EXHIBIT 5

State of Oklahoma v. Tyson Foods, Inc., et al

Expert Report

November 18, 2024

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1 INTRODUCTION

1.1 Qualifications

E&S Environmental Chemistry, Inc. (E&S), based in Corvallis, Oregon, has conducted environmental research and consulting projects nationwide for government, industry, and stakeholder groups since 1988. Clients have included nearly all federal agencies with natural resource responsibility, three national laboratories, and environmental quality departments in seven states. E&S has substantial expertise and experience in water quality monitoring, environmental compliance, nonpoint source pollution assessment, elemental mass balance, geospatial applications, watershed characterization, statistical and process-based modeling, environmental education, and terrestrial and aquatic effects research. The E&S team has developed numerous watershed analyses and assessments using federal and state methodologies. Each assessment has explored such issues as fisheries, wetlands, aquatic and riparian habitats, sedimentation, hydrology, water use, water quality, land use, channel habitat types, and stream channel modifications. E&S has leveraged extensive use of spatial data for resource evaluation, assessment, and linking of watershed conditions to current and historical land use patterns within watersheds.

Dr. Todd McDonnell is the President and Principal Scientist of E&S and has worked collaboratively with E&S co-founder Dr. Timothy Sullivan for more than 20 years. Sullivan and McDonnell collaborated on the development of Sullivan's 2009 Expert Report related to this Illinois River Watershed (IRW) litigation. McDonnell and Sullivan co-authored the Expert Report contained here.

Dr. McDonnell is an environmental scientist with 25 years of experience in water quality assessment, environmental modeling, harmful algal blooms, and agricultural best management practices. He has extensive experience with risk assessment to inform decision making related to anthropogenic impacts on a wide range of environmental components including water and soil chemistry, fisheries, and vegetation. Dr. McDonnell has developed watershed assessments to evaluate physiochemical and biological conditions including aspects of hydrology, water quality, soils, fisheries, wildlife, vegetation, and land use throughout the United States. Dr. McDonnell is experienced with implementation and monitoring related to agricultural best management practices for nutrient pollution reduction. He has served as the principal investigator and technical lead on a wide variety of collaborative environmental research and restoration projects conducted by E&S in cooperation with federal agency scientists and academic researchers throughout North America and Europe. Most have focused on environmental pollution and its effects on aquatic and terrestrial systems.

Dr. Sullivan is an environmental scientist with expertise in the areas of environmental chemistry, ecology, and zoology. He has 45 years of experience studying the influence of land use on the water quality of lakes, rivers, and streams. This includes about 35 years of experience conducting watershed assessment and research to determine relationships between human activities in the watershed and the quality of surface waters.

1.2 Purpose

E&S Environmental previously prepared an expert report in this matter addressing various aspects of phosphorous and bacteria in the IRW, and in January 2010 Dr. Timothy Sullivan testified at trial based on that report. E&S Environmental has now been asked by the Defendants to prepare a further report addressing the current state of the IRW, including anthropogenic changes and nutrient management practices, and to assess the availability, suitability, and efficacy of various remedies that may be proposed by the Plaintiff, the State of Oklahoma ("the State"), at a forthcoming hearing.

This report proceeds in two steps. First, we describe some of the significant changes that have occurred in the IRW since trial ended in 2010. We do not attempt to offer a comprehensive catalog of all changes in the watershed, or a complete assessment of poultry farming in the IRW. Doing so would have been challenging under any circumstances, and would have been impossible in the roughly 12-week timeframe we were provided. Instead, we focused on issues that have the potential to confound an assessment of the presence of any current injury and any remedies proposed to address any such injury. As the discussion below shows, the IRW has changed in significant ways including aspects related to human population, land use, and poultry farming.

Second, the Report discusses "remedies" that might be proposed by the State. The Court has required the parties to disclose expert reports simultaneously, and we understand the State refused to share in advance what remedies, if any, it might raise at the hearing. Accordingly, this report focuses on the 11 remedies discussed previously by the State's expert Mr. Todd King. As discussed below, the State has failed to demonstrate that any of Mr. King's remedies would alleviate harm purported to have been caused by the Defendants. None of Mr. King's remedies are available for use or are likely to have a significant impact on water quality in the IRW. In our view, no remedy proposed to this Court would have a superior positive impact on water quality as compared with the regulatory programs the States of Oklahoma and Arkansas already have in place. We will address any new or different testimony offered by the State at the hearing.

1.3 Summary of Findings

Finding 1: A robust framework for safely managing poultry litter in the Illinois River Watershed has been established through various laws and regulations, agreements, watershed management plans, educational outreach, and conservation partnerships.

Finding 2: The poultry litter industry has undergone extensive changes in relation to how poultry litter is managed in the Illinois River Watershed. These changes have minimized risk of phosphorus runoff to surface waters that could result from land application of poultry litter.

Finding 3: For the various reasons described in the "Missing Required Information" portions of Section 3 associated with each remedy proposed by King, no remedy is available to address purported phosphorus runoff related to land application of poultry litter in the Illinois River Watershed.

Finding 4: The State has presented no evidence that legacy phosphorus from land application of poultry litter is contributing to injury in the Illinois River Watershed. As such, any remedy associated with treatment or removal of existing phosphorus in sediments is not available.

Finding 5: The existing framework for managing land application of poultry litter includes penalties to ensure its rules and regulations are followed in a manner that prevents injury to the Illinois River Watershed from land application of poultry litter.

Finding 6: Any efforts to strengthen the rules and regulations related to managing land application of poultry litter should be implemented through the existing poultry litter management framework, which is being led by the natural resource agencies in Oklahoma and Arkansas, in coordination with stakeholders.

Finding 7: Urbanization and increased human population have been rapidly occurring in the headwaters of the Illinois River Watershed for several decades and will continue to increase. This increasing urbanization and human population have contributed and will continue to contribute phosphorus to surface waters of the Illinois River Watershed each day, rain or shine.

Finding 8: Remedies for urban point and non-point sources of pollution should continue to be addressed through the existing 2018 Memorandum of Understanding between the Oklahoma and Arkansas, and respective Watershed Management Plans and Watershed Improvement Plans developed by natural resource management agencies of the two states.

2 CURRENT WATERSHED CONDITIONS

2.1 Urban Land Cover and Humans

Over the past two decades, the IRW has experienced significant changes in land cover. These changes have been most pronounced in Northwest Arkansas. According to the National Land Cover Dataset, urban land cover in the headwaters of the IRW increased by 64% (+29 sq. miles) between 2001 and 2021 and by 12% (+8 sq. miles) between 2008 and 2021 (Figure 1). The four largest cities in the IRW (Bentonville, Rogers, Springdale, and Fayetteville) are predominately located in the headwaters of the watershed (Figure 1). According to estimates from the U.S. Census Bureau, the combined population of these cities increased by approximately 30% from 2001 to 2008 (173,154 in 2001 to 224,718 in 2008) and approximately 40% from 2008 to 2021 (224,718 in 2008 to 313,410 in 2021). The large increases in human population and urban land use would be expected to cause increases in phosphorus concentrations in surface water via multiple mechanisms, including application of lawn fertilizer, pet waste, soil disturbances, road construction, and wastewater treatment, among others. This area is estimated to reach 1 million residents by 2050.[1]

Urbanization and increase in human populations have several significant impacts on water quality, particularly through increasing phosphorus levels in surface waters. Numerous interconnected factors contribute to this effect. Two phases of urbanization cause adverse effects on receiving water quality. During the initial phase, a pulse of sediment and associated nutrients moves from disturbed land on construction sites to nearby surface waters. A subsequent more sustained phase is associated with increased runoff from impervious surfaces. This results in increases in transport of accumulated particulate and dissolved constituents during storm events, among other human-induced impacts to water quality year-round. Surface waters impacted by urbanization can suffer from increased turbidity, organic matter, temperature, and nutrient loads; as well as bacterial contamination (WEF/ASCE, 1998).

Urban development involves large-scale soil disruption, which increases soil erosion and runoff. Eroded soils are transported to surface waters, increasing phosphorus concentrations and promoting eutrophication. The expansion of urban areas leads to more impervious surfaces, such as roads, rooftops, sidewalks, and parking lots. These surfaces prevent natural infiltration of rainwater, leading to increased runoff that rapidly collects pollutants, including phosphorus, from the urban landscape. This runoff contributes to phosphorus loading in surface waters, as water can flow directly into streams and rivers without filtration by soils. Additional land use within urban areas can include residential lawns and landscaping, which often rely on phosphorus-containing fertilizers to enhance growth. This additional phosphorus source enters surface waters through stormwater runoff, further exacerbating phosphorus pollution. Over-application of fertilizers in urban areas or rainfall following fertilizer application can increase phosphorus contributions to nearby surface waters including streams, rivers, and lakes. The commercial fertilizers used in urban areas contain water-soluble phosphorus that is immediately bioavailable, unlike most of

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[1] Worth Sparkman, *Northwest Arkansas' Population on Track for a Million by 2050*, Axios NW Arkansas (Apr. 2, 2024), http://bit.ly/4fP1QxT

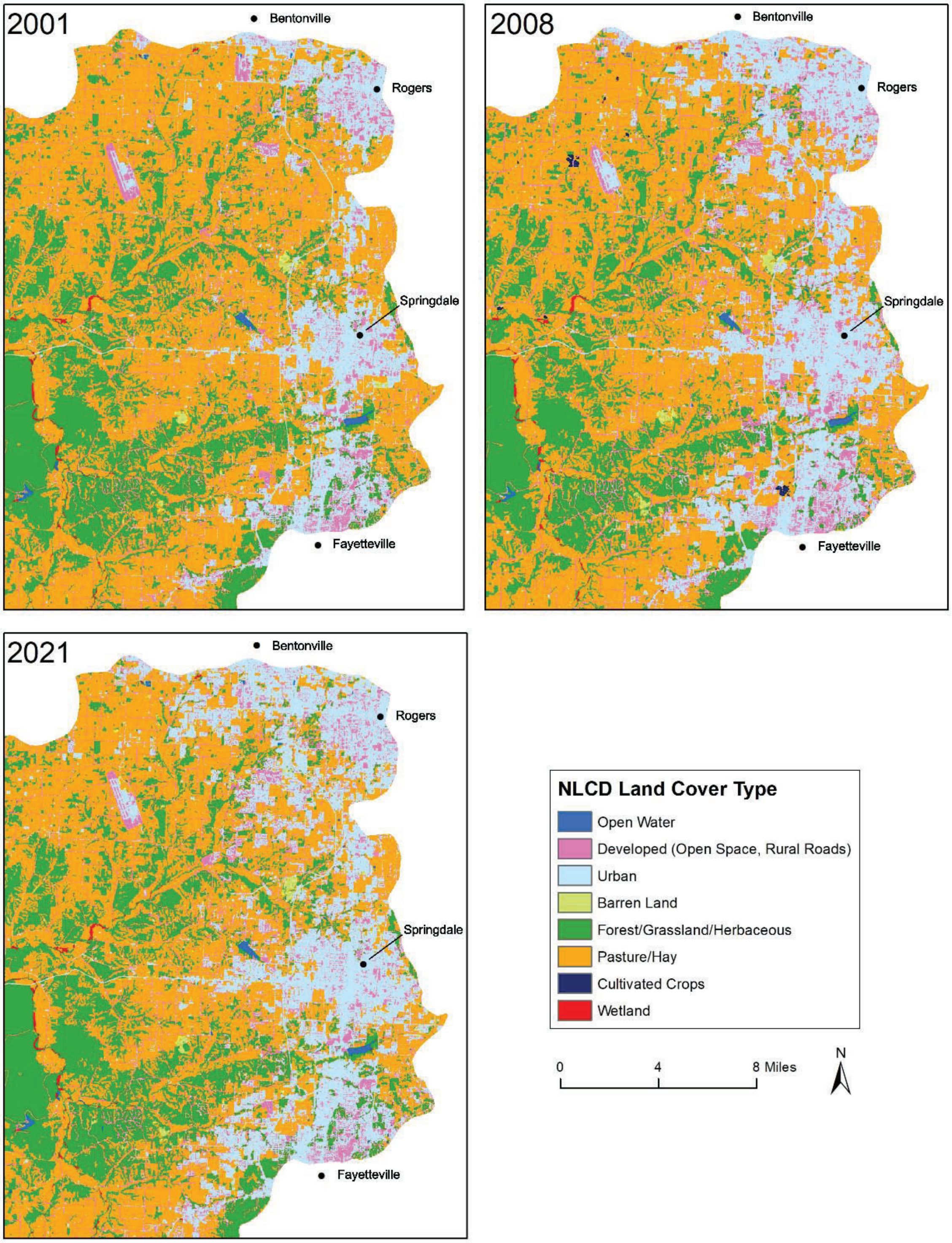

Figure 1. National Land Cover Database (NLCD) data for the northeastern portion (i.e., headwaters) of the Illinois River Watershed (IRW) from 2001, 2008, and 2021. Urban land cover in the headwaters of the IRW increased by 64% (+29 sq. miles) between 2001 and 2021 and 12% (+8 sq. miles) between 2008 and 2021.

the phosphorus in poultry litter. As human population density increases, wastewater production increases as well. Although phosphorus concentrations in wastewater effluent may remain somewhat stable during population growth, the overall volume of treated effluent entering receiving waters increases with the human population, leading to greater cumulative phosphorus loads. This additional phosphorus loading can degrade water quality and stimulate algal growth in downstream receiving waters.

These developments have changed the nature, location, and quantity of nutrient inputs into the waters of the IRW from the time of trial in 2009 and prior.

2.2 Poultry Production in the IRW

The number and location of poultry farms associated with most Defendants has changed significantly over the past 15 years. Prior to trial in 2008-2009, each Defendant identified to the Plaintiff the number and location of poultry farms raising birds for it. In the intervening years, that has changed significantly, and many farms that were growing birds for various defendants at that time are no longer doing so (Table 1).

Table 1. Poultry growers operating in the (IRW) identified in 2008-2009 by Defendant remaining in 2024.

Defendant	Growers Identified in 2008-09 by Defendant	Of those, remaining in the IRW in 2024
Cobb-Vantress, Inc.	89	18
Tyson Chicken, Inc.	243	42
Tyson Foods, Inc.	91	3
Tyson Poultry, Inc.	300	30
Peterson Farms, Inc.	40	0
Georges Farms, Inc.	51	7
Cargill	45	6

Thus, with respect to each defendant, poultry are being raised in different quantities and/or at different locations, and poultry litter is being generated and used or transported from different locations. Poultry houses have been removed from some farms. Some of those locations were converted into non-agricultural uses such as residential subdivisions and other urban landscapes. Some of the Defendants have replaced former IRW farms with farms located outside the IRW.

2.3 Arkansas and Oklahoma Programs for Poultry Growers and Litter Applicators

In the IRW today, pursuant to the laws of Oklahoma and Arkansas, land application of poultry litter is governed by nutrient management plans. These site-specific nutrient management plans permit land application of poultry litter to portions of fields that are not prone to surface transport because they do not routinely flood, are not frozen at the time of litter application, and are not located in close proximity to a stream. Additionally, nutrient management plans consider the soil

test phosphorus (STP) value for each field as part of the basis for determining appropriate litter application rates. The phosphorus content of the litter being spread is also considered in conjunction with the STP value for each field. Plans are updated at least every 5 (Arkansas) or 6 (Oklahoma) years. Okla. Admin. Code § 35:17-5-3(b)(4); Ark. Admin. Code 138.00.21-2204.3(C). These regulations were crafted to minimize the potential for phosphorus runoff resulting from land application of poultry litter. Nutrient management plans are developed under specific technical guidelines. Soil sampling and laboratory analysis are conducted in accordance with land grant university guidance and industry practice. Nutrient management plans are based on current scientific understanding that recognizes that both source and transport issues are important in nutrient management. When farmers follow these prescriptions, they act in compliance with existing laws and with current scientific understanding regarding management of non-point source pollution.

2.3.1 Arkansas

The Arkansas Soil Nutrient Application and Poultry Litter Utilization Act was enacted by the Arkansas Legislature in 2003. The Arkansas Natural Resources Commission (ANRC) established "Rules Governing the Arkansas Soil Nutrient and Poultry Litter Application and Management Program." Those rules became effective in 2006. Additionally, based on 2005 amendments to the Act, the requirement for managing land application of poultry litter in Arkansas was established in 2007, with the implementation of a nutrient management plan structure to govern land application of poultry litter within a nutrient surplus area.

Following enactment of legislation in 2003, the ANRC provided a "protective rate" for poultry litter application to be used as an interim measure. The protective rate set limits on application of poultry litter or commercial fertilizer in nutrient-limited areas where landowners had not yet obtained nutrient management plans for their land. The protective rate for poultry litter application expired January 1, 2007, after which any operation applying phosphorus was required to have a Nutrient Management Plan or a Poultry Litter Management Plan.

Much of the water quality data examined at trial pre-dated the widespread adoption of nutrient management plans. Today, Arkansas's poultry litter regulations have been in place and operating for nearly two decades. According to the Upper Illinois Watershed Management Plan, presently all poultry growers are expected to be managing operations according to nutrient management plans.[2]

The Arkansas Natural Resources Commission (ANRC) Rules Governing the Arkansas Soil Nutrient and Poultry Little Application and Management Program utilize a "Phosphorus Index" to be referenced in all nutrient management plans and to "govern the terms and conditions under which Nutrients may be land applied." ANRC revised the rules effective January 1, 2010, to

[2] Arkansas Dpt. of Ag., Upper Illinois River Watershed Management Plan (Oct. 2024); Patrick Fisk, Personal Communications.

replace the original Phosphorus Index (developed in 2001) with a new Phosphorus Index (developed in 2009).

2.3.2 Oklahoma

The State of Oklahoma, through the Oklahoma Poultry Waste Applicators Certification Act, has established a comprehensive program that ensures standards for land application of poultry litter, work performance, applicator certification and recertification, and procedures and best management practices are followed (Oklahoma Dep't of Agriculture, *Agricultural Environmental Management Division*, https://bit.ly/3CGOzZY (last visited Nov. 17, 2024)) .

The State of Oklahoma regulates poultry feeding operations and litter land application through the Oklahoma Registered Poultry Feeding Operations Act (ORPFOA) and the Oklahoma Poultry Waste Applicators Certification Act (OACA), both of which were enacted in 1998. The ORPFOA requires all poultry feeding operations to register with the Oklahoma State Board of Agriculture, adopt Best Management Practices (BMPs), procure and comply with an Animal Waste Management Plan (AWMP), including litter application rates and associated instructions, and test poultry litter and the soil to which it may be applied on an annual basis. The State Department of Agriculture, Food, and Forestry (ODAFF) is charged with administration and enforcement of the OACA. The department has the authority to suspend, cancel, deny, or revoke applicator certificates. ODAFF enacted regulations for both ORPFOA and OACA to ensure the beneficial use of poultry waste while preventing adverse effects on waters of the State. The ODAFF regulations described the factors that control the amount, location, and manner in which poultry litter may be applied to any particular field based on soil tests, litter tests, and site characteristics.

AWMPs are field-specific plans setting forth the time, location, and amount of poultry litter that may be applied to a parcel of land. An AWMP must set forth "land application rates of poultry waste based on the available nitrogen and phosphorus content of the poultry waste and provide controls for runoff and erosion as appropriate for site conditions" based on "a soil test and current "application rate based upon the Department's standards for land application for poultry waste as promulgated by rules." [USDA Natural Resources Conservation Service (NRCS)] phosphorous standards." Okla. Stat. tit. 2 § 10–9.7(C)(5), (G)(3).

AWMPs also incorporate Best Management Practices (BMPs), including all those set forth in the ORPFOA and accompanying regulations. Okla. Stat. tit. 2 § 10–9.7(A), (B). An AWMP contains prohibitions against litter application in certain circumstances, including when the ground is saturated or during rainfall events or when it is frozen. It prohibits application to locations within 100 feet of a perennial stream, within 50 feet of an intermittent stream and to fields with a slope greater than 15 percent or soils less than 10 inches in depth.

Oklahoma regulations authorize the drafting and issuance of AWMPs on behalf of the State by the USDA NRCS or an entity approved by the State Department of Agriculture. Currently, AWMPs are drafted by soil scientists under contract with ODAFF, each of whom possesses training and expertise in this field. Each AWMP is tailored to the characteristics of the specific parcel of land

to which the AWMP relates. Each plan incorporates the requirements from the statutes and the rules, but it also may incorporate particular issues that are associated with that individual's property, including proximity to streams.

The ORPFOA mandates that approved AWMPs include BMPs and provisions designed to prevent discharge of poultry waste to the waters of the state and no contamination of the waters of the state. Under ORPFOA, the procedures documented in the AWMP require that poultry waste shall only be applied to suitable land at appropriate times and rates. Discharge or runoff of waste from the application site is prohibited. If either occurs, the provisions of the ORPFOA require the particular AWMP to be assessed and revised to address any noted deficiencies. Similarly, ODAFF's AWMP Requirements mandate that storage and land application of poultry waste shall not cause a discharge or runoff of significant pollutants to the waters of the state. In 2024, the Oklahoma legislature amended Oklahoma law to confirm that the state agents tasked with drafting and approving plans are expected to prepare plans that minimize the risk of runoff. Accordingly, that same law makes clear that those applying litter in conformance with a plan are not liable for a nuisance. Okla. S.B. 1424 (May 31, 2024).

The OACA requires that anyone who applies poultry litter, whether as a commercial or private applicator, must first obtain an applicator's certificate from the State Board of Agriculture. The OACA also requires litter application to comply at all times with the provisions set forth in the Animal Waste Management Plan, if application is conducted on land operated by a registered poultry operation. All other applications in a nutrient-limited watershed must comply with a Conservation Plan.

The ORPFOA requires all poultry growers and all certified applicators to receive nine hours of education regarding poultry waste handling in the first year and two hours of continuing education every year until the operator has received a total of 19 hours of training; thereafter, growers and applicators must receive two hours of continuing education every three years. The training is generally provided through the Oklahoma State University Extension Service and usually includes participation by ODAFF officials in educational programs and training videos.

IRW growers appear to operate in compliance with their nutrient management plans. The State provided no evidence at trial of substantive violations of nutrient management plans. All growers and applicators uniformly testified at trial that they comply with all specifications included in their nutrient management plans, including litter application rates.

Oklahoma's statutes and regulations set maximum limits on litter application that are dependent on whether the land targeted for application is located in a "Nutrient Limited" or "Non-Nutrient Limited" Watershed. In nutrient limited watersheds, litter may not be applied at the full rate to any land with an STP level greater than 120 lbs/acre, and all application is prohibited on lands in excess of 300 STP. Since July 1, 2006, the State of Oklahoma has designated the Oklahoma portion of the IRW as "Nutrient Limited". Prior to July 2006, the non-nutrient limited Code 590 standards applied to the IRW, which included an STP cap of 400 lbs/acre at that time.

2.4 Agronomic Practices and Litter Handling in the Oklahoma and Arkansas IRW

2.4.1 Poultry Litter Management and Agronomic Practices

Management of poultry houses by poultry farmers has changed dramatically over the past 15 years. In 2009-2010, growers typically cleaned out their houses at least once per year; today, growers clean out houses on average every 3 to 7 years. This change was driven principally by an improved understanding of bird health.[3] (Patrick Fisk, Personal Communications).

Rather than clean-out, growers will de-cake and windrow their litter, and then re-spread it within the house, perhaps with a fresh top layer of bedding material. De-caking is the removal of the moisture-heavy, crusted top layer. Litter has a tendency to retain moisture and clump together in a process which is referred to as ‘caking’. This caked material is undesirable because it increases house ammonia levels, resulting in adverse effects on flock performance (Miles et al., 2004). De-caked material can be land-applied or stored in a stacking shed awaiting sale and transport.

Windrowing is now a common practice to control pathogen populations and disease risk associated with longer in-house litter retention times. Linear windrows of litter are formed at 18 to 24 inches in height along the length of the house between flocks and turned at least once prior to placement of the next flock. The high temperatures achieved during windrowing work to pasteurize the litter. Leveling of windrows four to five days prior to chick placement will allow for ammonia release as the litter cools and dries. Another method used for managing poultry litter for extended in-house retention is through a ‘partial house cleanout’ during which a limited amount of litter from the middle portion of the house is removed, with the remaining litter redistributed throughout the house.[4]

Growers also now use other methods that address the nutrient content of poultry litter. Many companies, including Tyson, Simmons, and Georges, include additives in their feed (e.g., phytase) to make the nutrients in the feed more available for absorption by the birds, resulting in fewer nutrients in bird waste (Philip Smith, Personal Communication). Phytase-supplemented poultry diets often contain 15 to 25 percent less phosphorus than conventional diets. As a result, more phosphorus provided directly in the feed is retained in the bird and manure phosphorus excretion from animals provided phytase-supplemented diets is reduced 15 to 25 percent compared to manure from birds that have been provided conventional diets. Many growers also now treat poultry litter in the houses with alum. Alum has the effect of binding phosphorous in the litter in a non-bioavailable form.

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[3] Oladeinde, et al., Litter Commensal Bacteria Can Limit the Horizontal Gene Transfer of Antimicrobial Resistance to Salmonella in Chickens, 88 Applied & Env’t Biology 9 (2022) (available at https://doi.org/10.1128/aem.02517-21); Julienne Isaacs, Poultry litter: How old is too old?, Manure Manager (Oct. 18, 2021), https://www.manuremanager.com/poultry-litter-how-old-is-too-old/; Poultry Environmental Quality Handbook, Recycling of Poultry Litter, Univ. of Georgia College of Agric. and Env’t Sciences (last accessed Nov. 16, 2024), https://peqh.uga.edu/2023/10/recycling-poultry-litter/; John A. Smith, The case for built-up litter in US broiler complexes, The Poultry Site (May 9, 2017), https://www.thepoultrysite.com/news/2017/05/the-case-for-builtup-litter-in-us-broiler-complexes. (Josh Payne Personal Communication).

[4] Tom Tabler & Jessica Wells, *Poultry Litter Management*, The Poultry Site (Dec. 17, 2012), https://bit.ly/3YLvugA.

Eventually, litter is cleaned out and either land applied by the poultry grower according to their nutrient management plan or sold to a litter stockpiler, transporter, or certified poultry litter applicator. These new methodologies promote bird health and are more economically advantageous for growers.

The State of Oklahoma, primarily through the Oklahoma State University Extension (OSU Extension), provides a variety of educational materials related to poultry litter management, including fact sheets and publications that address topics such as soil sampling, nutrient management, water quality, and other aspects of poultry litter management.

The OSU Extension website includes a dedicated section for poultry waste management education (Okla. St. Univ. Extension, *Poultry Waste Management Education*, https://bit.ly/4fvvjgN (last visited Nov. 17, 2024) with links to practical poultry litter management resources including the Oklahoma Litter Market and the Poultry Litter Transfer Program. Additionally, the OSU Extension facilitates cooperation among stakeholders to address challenges through voluntary programs to identify problems and implement solutions. Training topics include:

- Regulations
- Environmental Background
- Understanding the Nutrient Management Plan
- Poultry Litter Nutrient Management
- Soil & Litter Sampling, Spreader Calibration
- Litter Use as a Soil Amendment
- Conservation Practices
- Alternative Waste Management Technologies
- Poultry Litter Commerce

These OSU Extension resources constitute an important part of the overall poultry litter management framework that has become increasingly robust since 2008. These services are integral to sustainable poultry litter management in the IRW. Oklahoma State University has a strong track record in agricultural research, with a focus on practical solutions for farmers and ranchers. They have made significant contributions to improving crop yields, livestock production, and sustainable agricultural practices. Moving forward, the expectation is that OSU will continue to be a leader in agricultural education and research, including the advancement of innovative methods for managing poultry litter to reduce environmental impact.

2.4.2 Poultry Litter Application and Transportation

The patterns of poultry litter transportation and application have changed dramatically in the IRW over recent decades. Less litter is land-applied, and vastly more litter is transported significant

distances away from the IRW. As early as 2010, over 100,000 tons of poultry litter was being annually exported from the IRW in Arkansas and Oklahoma, most of which was moved to Kansas and central Oklahoma.[5]

Various efforts have helped to expand the litter export industry in the IRW. The Oklahoma Litter Market, provided through the OSU Extension lists sellers of poultry litter and service providers. The OSU Extension has developed a Poultry Litter Transfer Program that provides incentives for poultry growers to sell litter to a qualified buyer and litter buyers to offset the cost of transport. The Oklahoma Conservation Commission (OCC) has supported the transfer of poultry litter out of nutrient-impacted watersheds (OCC, *2022 Litter Transfer Rules* (Jan. 1, 2022). Buyers and sellers work with local conservation districts to arrange litter transport and ensure compliance with regulations. Furthermore, poultry integrators in the IRW have supported the removal of litter directly from farms they operate, and have also provided financial incentives to facilitate the export from the IRW of poultry litter generated on contract grower farms through a nonprofit corporation named BMPs Inc. Since 2005, annual export of poultry litter reported by BMPs Inc. increased from approximately 15,000 tons/yr to well over 100,000 tons/yr in recent years. (BMPs, Inc. data sheet Exports 2005-2023).

Data accumulated by the State of Arkansas demonstrates that from 2014 to 2023, an increasingly small fraction of poultry litter generated in the IRW was land applied near where it was generated, around 7% on average in the Benton and Washington counties in the Arkansas IRW. Roughly 80% of the total average 189,369 tons of litter generated in the IRW annually was sold or transferred from these counties from 2014 to 2019, with a significant portion of it appearing to leave the State entirely. (ANRC Annual Data 2014-2023). In 2023, the most recent year for which data is available, in Benton County, growers generated 205,443 tons of litter, of which growers removed 134,699 tons from the houses, land applied 3,740 tons, stored 3,244 tons, sold 127,697 tons, with the remaining 18 tons unaccounted for.[6] Data for Washington County reflects the same trend – 102,106 removed from houses; 7,345 tons land applied; 92,621 tons sold and transported. (ANRC Data 2023)

ODAFF data show that the land application of litter "in the Oklahoma IRW dropped from 31,660 tons in 2009 to 7,700 tons in 2010." (Herron, et al.). According to ODAFF, 12,774 tons of poultry litter were applied within the Oklahoma IRW from July 1, 2017 through June 20, 2018. Additionally, 34,590 tons of poultry litter originating from within the Oklahoma portion of the IRW was either land applied outside of the IRW in Oklahoma or exported to other states from July 1, 2017 through June 20, 2018.[7] As an example, Adair County was a net importer of poultry litter

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[5] Tomlinson Proposal for 2014-2015 Kansas Fertilizer Research Fund at 1 (citing Herron, S, A. Sharpley, S. Watkins, and M. Daniels. 2012. Poultry Litter Management in the Illinois River Watershed of Arkansas and Oklahoma. Cooperative Extension Service, Division of Agriculture, University of Arkansas. Fact Sheet FSA9535 at 3.

[6] These data sets are not perfect, which is not surprising on account of the self-reporting nature of the data. What matters for my purposes, however, is that the changes in liter handling is changed by orders of magnitude from the time of trial when, as the Court found, most litter was land applied by growers near where it was generated.

[7] Jeremy Seiger, Dir. ODAFF, Report on Poultry Waste Movement (Apr. 19, 2019).

in 2001 (i.e., 113% of the amount generated was applied). This proportion of poultry litter applied decreased to 51% in 2006 and to 33% in 2013. (ODAFF Data 2018; OCC Data 2001, 2006, 2013).

Thus, poultry litter that was once mostly land applied in close proximity to where it was generated in the IRW is now transported outside the watershed. Less is land applied near the houses where it was produced. Whereas in 2009-2010, BMPs accounted for most litter export from the IRW, a robust private market of buyers, stockpilers, and transporters now exists (OSU Litter Market; Patrick Fisk, Personal Communications).[8] More recent data show that a substantial amount of the litter generated and removed from poultry farms in the IRW is exported outside the IRW. The available records from Arkansas and Oklahoma during this period indicate that about 80% to 90% of litter is shipped off the farms where it is generated.

2.5 Watershed Management and Partnerships

In response to a 2018 Memorandum of Agreement (MOA) between Arkansas and Oklahoma, both states agreed to develop and begin the process of implementation of a Watershed Improvement Plan (WIP) and to establish a Monitoring and Assessment Workgroup. Additionally, each state agreed to prepare a nine-element Watershed Management Plan addressing nonpoint sources of phosphorus and other pollutants of concern. In 2022, to describe the collaborative nature and long-term vision of these plans to manage the IRW, Shanon Phillips of the Oklahoma Conservation Commission stated: "The Oklahoma Conservation Commission (OCC) and the Arkansas Natural Resources Division (ANRD) are working collaboratively to host a series of stakeholder meetings that will guide the update of the Illinois River Watershed management plan for the next decade."[9]

A watershed management plan had previously been developed for the Upper IRW in 2012 (FTN Associates, Ltd. July 17, 2012. Watershed-Based Management Plan for the Upper Illinois River Watershed, Northwest Arkansas.). Given the changing landscape of the Illinois River Watershed, the Upper Illinois River Watershed Management Plan has been updated to re-evaluate current water quality conditions, target sub-watersheds for implementation of conservation practices, and engage existing and new stakeholders. This updated plan also established new goals for water quality improvements as a US EPA-approved nine-element watershed management plan. The existing Oklahoma Watershed Management Plan was developed in 2010. Updates to this plan for acceptance by US EPA remain in progress.

Upon acceptance by US EPA, these plans allow for federal funding for conservation practices in the watershed. The Watershed Management Plans and the WIP are connected because two of the nine elements from the Watershed Management Plans will be incorporated into the WIP.

[8] Oklahoma State University Extension, Oklahoma Litter Market: Sellers and Service Providers (Summer 2022), https://extension.okstate.edu/programs/poultry-waste-management/media/oklahoma-litter-market-2022.pdf; Poultry Environmental Quality Handbook, Economics of Transporting Poultry Manure and Litter, Univ. of Georgia College of Agric. & Envt'l Sciences (last accessed Nov. 17, 2024), https://peqh.uga.edu/2023/09/economics-of-transporting-poultry-manure-and-litter-2/.
[9] https://conservation.ok.gov/events/first-public-meeting-for-illinois-river-watershed-management-plan-set-for-october/

Additionally, the WIP "will include and update 319 projects and a WIP Advisory Group. The WIP will identify possible water-quality improvement strategies for point and nonpoint sources outlined in each states' watershed based management plans (Ark. Energy & Env't, *Integrated Water Quality Monitoring Assessment Report* (2020))."

The updated Upper Illinois River Watershed Management Plan describes a set of conservation practices to be used for addressing potential non-point sources of pollution, including utilization of nutrient management plans for farmland and implementation of best practices for urban storm water management. Furthermore, the Illinois River Partnership has been established to: "improve the integrity of the Illinois River Watershed through public education, outreach, and implementation of conservation and restoration practices throughout the watershed" (Illinois River Watershed Partnership, *Our Mission*, https://bit.ly/3AOtlZN (last visited Nov. 17, 2024)).

3 RETAINED REMEDIAL OPTIONS

At the trial held in this matter previously in 2009-2010, the State offered some testimony relating to remedies from Mr. Todd King. In his report and testimony, Mr. King identified a number of potential remedies that, he posited, might theoretically be used to address excess phosphorus in the IRW (King 2008). At trial, King testified "I classified them as either retained for further evaluation within this report, or requires additional investigation and assessment because I didn't have enough information to do much within this report, and then finally not retained." (Trial Tr. 7995). Mr. King "retained" three remedies: (1) cessation of land application of poultry litter, (2) installation of riparian buffer strips, and (3) increased treatment of drinking water. In addition, Mr. King proposed that eight additional remedies be "further assessed": (1) localized soil excavation, (2) alum application to fields, (3) crop and nutrient management with nitrogen supplementation, (4) stream bank stabilization, (5) constructed wetlands, (6) alum application to Tenkiller Lake, (7) sediment removal from Tenkiller Lake, and (8) layered aeration of Tenkiller Lake. This report addresses these remedies previously raised by Mr. King. We will address at trial any additional discussion the State offers as to these or as to any different remedies the State subsequently raises.

Whether a remedy is appropriate to address an injury depends on a number of factors. First, a remedy must be available, in that it reflects proven technologies and methods, with known effects and consequences. Second, a remedy must be implementable. It should be possible for the court to order and the defendant to effectuate the remedy as a practical matter based on current conditions. Third, a remedy must be effective, in that it addresses the alleged injury resulting from the challenged conduct.

In 2008, King developed a list of what he deemed possible remedies. As King described his methodology, he attempted to "evaluate effectiveness and implementability," and considered cost as "really just a very rough criteria." (Trial Tr. 7994). However, none of King's proposed remedies was supported by data, fieldwork, detailed cost assessment, context of the IRW, health and safety factors, feasibility of land acquisition, or other logistics. King accepted opinions of other state experts as fact and failed even to examine whether any given remedy addressed the particular alleged misconduct and injury asserted in this litigation in the IRW. Without evidence and analysis tying a particular course of action to a particular harm, demonstrating both that the harm results from the alleged wrongdoing and that the proposed action will address that harm, there is no suitable remedy. King also makes no effort to account for third party factors that may confound the suitability or availability of any remedy, such as consent by the U.S. Army Corp of Engineers for any activity on Lake Tenkiller, or third party riparian landowners for whose land is necessary for vegetated buffer strips.

As a general matter, Mr. King did not do the work necessary to support any of his remedies. To the best of King's knowledge (Deposition, page 181), none of the remediation goals outlined by King in his report have been documented previously by the state of Oklahoma in any official state document. King was not aware (Deposition, page 181) if any of the remediation goals specified in his report were ever presented to the public for comment. King was also not aware of any public process in development of his remediation goals (Deposition, page 182). King agreed (Deposition,

page 184) that he did not consider any comments from interested parties, such as poultry farmers, cattle farmers, poultry integrators, federal government, State of Oklahoma, State of Arkansas, Cherokee Nation, 3rd party landowners, municipalities, public utilities, etc., regarding his evaluation or development of remediation alternatives. Thus, there was little or no opportunity for anyone other than Mr. King, himself, to provide input regarding the remediation goals or remedies outlined in the King 2008 Report.

For each remedy proposed by King, the ensuing sections (1) characterize the proposed remedy, (2) identify concerns related to the proposed remedy, and (3) identify information missing and results of analyses not presented by the State to support the remedy.

3.1 Cessation

3.1.1 Characterization

King stated that cessation of land application of poultry litter must be implemented to begin addressing injuries identified for the rivers and streams of IRW and Lake Tenkiller. King further stated, however, that **poultry waste should be managed in accordance with applicable laws and regulations** and not allowed to negatively impact human health or the environment within or outside the IRW (King Report, page 11). King also stated that all other remedial action objectives offered in the report were predicated on cessation of land application of poultry litter within the IRW (King Report, page 6). As such, according to King, without cessation of poultry litter, none of the other remedial alternatives are available.

3.1.2 Critique

The two recommendations by King, 1) full cessation or 2) application consistent with existing laws and regulations, are inconsistent. Applicable laws and regulations do not require cessation of land application of poultry litter throughout the IRW. King provided no justification for his claim that all of his suggested remedies necessarily require cessation of poultry litter application. Managing poultry litter in accordance with applicable laws and regulations, and in association with best management practices, can ensure that poultry farmers and certified applicators are environmentally responsible in their land application of poultry litter (Harrison 2023). King agreed with this by stating that “poultry waste should be managed in accordance with applicable laws and regulations”, seemingly suggesting that if poultry litter is land applied according to nutrient management plans and in compliance with all other pertinent rules, then continued land application of poultry litter within the IRW would be appropriate. Given that nutrient management plans have been fully established, a robust litter management program for the IRW is already in place. Furthermore, the Court found that poultry litter is beneficial for use and can be land applied in some instances without environmental harm. Findings of Fact and Conclusions of Law on Defendants’ Motions for Partial Judgement, Docket No. 2884, ¶¶ 7-10. Examples of responsible poultry litter management can include avoiding application near rivers and streams, on steep slopes, or when the ground is frozen. All of these are considerations included in Nutrient Management Plans (NMP) and Animal Waste Management Plans (AWMP; hereafter collectively

referred to as "Nutrient Management Plan"). As discussed, these plans are developed for poultry growers and litter applicators in the IRW.

Although it is known that portions of the IRW are amendable to land application of poultry litter if such application is performed in conformance with applicable laws and regulations and associated nutrient management plans, King also stated that cessation of land application of poultry litter should occur throughout the IRW. If complete cessation of land application of poultry litter is actually what King meant by his recommended "cessation" remedy, then this recommendation cannot be considered as a remedy because there are, of course, areas of the IRW in which poultry litter can be applied in compliance with state-approved nutrient management plans.

Forced cessation would be inconsistent with the existing program of using STP and other guidelines for litter application management. Management plans, if properly drafted and followed, are effective. Oklahoma and Arkansas state programs are sufficient to address litter application issues. It seems inappropriate to overrule the state's legislatively-enacted statutes and the regulations developed by the state regulatory experts. The goal should be to build up the existing regulatory program.

While the agronomic rate to support forage crop growth is estimated at STP 65, the OSU Extension recommends at least STP 120 to ensure sufficient nutrients for full crop yield. Restricting application to STP 65 would risk increasing erosion and runoff from fields that lack full coverage on account of variability in STP and associated reduction in vegetation coverage in areas with STP below the agronomic demand.

A potential unintended consequence of cessation of land application of poultry litter, particularly wholesale cessation across a broad region, would be the removal of a valuable source of fertilizer on pastures used by farmers in the region (Harrison 2023). Cattle farmers in the IRW rely on poultry litter to fertilize the soil for the production of forage crops utilized for cattle grazing. As such, it is reasonable to assume that the cattle farming industry in the IRW would be adversely impacted by the lack of availability of poultry litter as a forage crop fertilizer.

Furthermore, it is possible or likely that some cattle farmers would replace poultry litter with inorganic fertilizers containing phosphorus, which could reduce or negate the intended benefits of broad-scale cessation of land application of poultry litter (Mark Weathers, Personal Communication). Requiring the use of inorganic fertilizer for cattle forage growth would have immediate effects on cattle farmers due to the higher cost of inorganic fertilizer relative to poultry litter. The price of inorganic fertilizer tracks the price of oil and gas due to the high energy requirements for inorganic fertilizer production. Given that oil and gas energy prices can be highly volatile, this volatility would be expected to be passed on to cattle farmers, introducing more uncertainty into the long-term sustainability of the cattle farming industry in the IRW.

The use of inorganic fertilizer is not expected to yield sufficient forage crop density to accommodate the current typical cattle stocking ratio of one head of cattle per 2.5 acres. Given the

likelihood of lower stocking ratios with less vigorous forage crop growth, a given acreage of land would be expected to yield fewer pounds of beef grown at higher costs. These higher costs would most likely be passed on to the consumer in a time of already high food prices and inflation. The long-term effect of cessation of land application of poultry litter on the region would be significant and potentially result in an overall reduction in the economic productivity of the IRW.

At present, application of poultry litter as a fertilizer is regulated. Commercial fertilizer application is not regulated in Oklahoma. Poultry litter contains bedding materials (e.g., wood shavings, rice hulls, and other plant-based material) that contribute nitrogen and phosphorus to soil in organic forms, which are less water soluble than inorganic forms of nitrogen and phosphorus. The slower release of organically bound nutrients is expected to result in less potential nutrient runoff as compared with inorganic nitrogen contained in urea fertilizer that transforms to nitrate compounds that becomes highly mobile during storm events. Organically complexed nitrogen contained in poultry litter is more durable in soils.

Organic-based poultry litter fertilizer contains micronutrients and has chemical effects that are likely to be difficult to replicate with inorganic commercial fertilizer. Poultry litter builds soil and improves the soil matrix. Organic-based poultry litter fertilizer contains a suite of nutrients to support healthy crop forage growth including nitrogen, phosphorus, potassium, calcium, magnesium, and micronutrients such as manganese and zinc. Replicating this suite of nutrients with application of inorganic fertilizers would likely be challenging for cattle farmers to manage and would increase the costs beyond those associated with supplementing nitrogen requirements with commercial urea. Urea-based fertilizers do not contain calcium, which is important for the maintenance of soil pH in the range (6.8 to 7.2) that promotes the desired forage crops for cattle (e.g., fescue, Bermuda). Although an N-only fertilizer such as urea may fully support desired forage crop growth for a few years, soil pH will diminish over time and the soil will require lime application to minimize undesirable grasses (e.g., broomsage) from encroaching into the more acidic and less fertile soils that are unsupported by organic-based poultry litter fertilizer. Marginal grass cover resulting from inadequate nutrient supply from inorganic fertilizer is more likely to lead to runoff and erosion than when soils are covered by dense forage crop cover supported by organic-based poultry litter fertilizer.

Poultry litter applicators are required to follow regulations related to land application of poultry litter. If a land area is deemed unsuitable for any land application of poultry litter, the cattle farmer would need to use commercial fertilizer and supplement with lime until the STP drops back into the range that would allow for at least some level of poultry litter application.

3.1.3 Missing Required Information

An IRW-scale determination has not been developed of where land application of poultry litter should be avoided. Areas of the IRW expected to yield the most benefit, in terms of minimizing the likelihood of phosphorus in runoff, in response to cessation of land application of poultry litter, are those with high STP values, on a steep slope, and that are located in close proximity to a stream. Although nutrient management plans developed for individual pastures aim to identify such

locations at present, only a small percentage of litter generated in the IRW is applied on that same poultry grower's land as poultry litter management practices have changed and more poultry litter is sold by growers and exported outside of the watershed. A broader scale analysis of where these higher risk areas may be located would be needed to consider adopting this cessation action at the watershed scale. An understanding of the extent to which cessation of land application of poultry litter in the IRW would affect other stakeholders (e.g., cattle farmers) has not been established.

The State of Oklahoma, through the Oklahoma Poultry Waste Applicators Certification Act, has established a comprehensive program that ensures that appropriate procedures and best management practices for land application of poultry litter are followed. Poultry growers and certified litter applicators in the IRW are known to operate in compliance with requirements of nutrient management plans or litter application procedures. The State provided no evidence, at trial or in intervening years, of violations of nutrient management plans or litter application procedures. Documentation of non-compliance with nutrient management plans or procedures would be needed to consider cessation of poultry litter application as a potential remedy beyond the areas in which cessation already occurs.

3.2 Buffer strips

3.2.1 Characterization

Buffer strips (also called "vegetated filter strips"; VFS) are used to reduce nutrient runoff from pasture lands, which are found interspersed among forest, urban, and other land cover types in the IRW. They are installed between an expected or possible non-point source of runoff and receiving surface water bodies (e.g., streams, rivers, or lakes). Vegetated filter strips slow water runoff which allows larger soil particles (and adsorbed phosphorus) to settle. The vegetation within the strip reduces the propensity for overland flow (e.g., as sheet flow or through formation of rills and gullies), thereby reducing nutrient runoff from fields to surface waters, facilitating nutrient uptake by plants.

Vegetated filter strips were suggested by King to potentially reduce nutrient runoff from pastures and grasslands to surface waters of the IRW. King suggested that vegetated filter strips should be developed within a width of 100 feet on both sides of streams and rivers that flow through pastures or grassland. The recommendation was for installation either across all such streams within IRW (estimated at 84,927 acres) or for streams 3rd order and above (estimated at 13,347 acres) (King report, page 25).

3.2.2 Critique

State regulations currently disallow land application of poultry waste within a 100-foot buffer of a perennial stream and 50-foot buffer of an intermitted stream for the purpose of minimizing phosphorus in runoff. Thus, 'buffer zones' of areas in which poultry litter cannot be spread are already in place in the IRW. King described that, although vegetated filter strips have been shown in some cases to be effective in reducing phosphorus runoff from fields to surface waters, this is

not always the case: "Vegetative filter strips (VFS) are not always effective at removing soluble P and N. (King report, page 25)".

The extent to which enhancing the vegetation within existing stream buffers would further reduce phosphorus loading to surface waters of the IRW is unknown. Enhanced stream buffers are likely to be most effective at nutrient capture in areas with a propensity to produce overland flow (i.e., sheet or rill/gully flow). Such areas are well known to individual farmers. Strategic use of cattle exclusion fencing around stream buffers would minimize impacts from cattle entering existing buffers and adjacent streams.

King did not take cattle management practices into consideration in specifying remediation efforts (King Deposition, page 51). King admitted in his trial testimony (page 8122) that cattle were not a focus of his report. In his testimony (page 8122), he stated that it was not better to have a buffer strip that was fenced as compared to one not fenced, with respect to phosphorus movement from land to stream. That is not true. Fencing cattle from the stream avoids phosphorus contributions from erosion and from contributions of cattle excrement directly to the stream and adjacent riparian zone.

Development and maintenance of riparian BMPs throughout the United States are commonly coordinated between state and local conservation or environmental protection agencies and agricultural producers on a voluntary basis, often with federal support. These types of BMPs are under consideration through Watershed Management Plans for the IRW.

3.2.3 Missing Required Information

The extent to which enhanced buffer strips (i.e., modifications to existing buffer zones) may further reduced the risk of non-point source pollution in the IRW has not been determined.

Forcible means would likely be needed to acquire the land on which to enhance vegetated filer strips. This is not practical to implement across the estimated 13,347 to 84,927 acres recommended by King for consideration. In the event that a land area is forcibly acquired for development or enhancement of a vegetated filter strip, the manner in which the filter strips would be developed or enhanced and maintained would need to be determined.

Developing vegetated filter strips along all streams (or all 3rd order and larger streams) that flow through all pastureland in the IRW is not practical. An analysis would be needed of which stream lengths should be provided with vegetated filter strips because they are shown to be contributing to injury and such contributions have been shown to be causally connected to the activities of the Defendants. However, there has been no determination of the extent or location of such stream lengths. Given that a remedy is only available if it addresses the purported injury, vegetated filter strips cannot be considered a remedy because the locations of the theorized source of the injury have not been identified.

3.3 Increased treatment of drinking water

3.3.1 Characterization

Implementation of water treatment technology was suggested by King as a method to address the potential for formation of disinfection byproducts (DBPs), including trihalomethanes (THMs) and haloacetic acids (HAA5s), in drinking water. It has been suggested that DBPs result from increased organic matter in surface waters in the IRW, purported to have resulted from elevated phosphorus in runoff from land applied poultry litter.

3.3.2 Critique

Organic matter is correlated with precursors that form DBPs when drinking water is disinfected. The formation of disinfection byproducts such as THMs and HAA5s can be reduced by using enhanced coagulation, softening or granular activated carbon (GAC) to remove these precursors. To determine the extent to which phosphorus in runoff from land applied poultry litter may have increased the formation of DBPs in drinking water supplies of the IRW, a source apportionment analysis would be needed.

3.3.3 Missing Required Information

No study has been performed to determine how any particular remedy would impact the treatment of drinking water in the IRW. There has also been no documented causation of injury from land application of poultry litter in relation to drinking water or formation of DBPs. Quantification of such a causation would be needed prior to consideration of increased drinking water treatment as a remedy. Given that a remedy is only available if it addresses a purported injury, increased drinking water treatment cannot be considered a remedy because the locations of the theorized source of the injury have not been identified.

4 WATERSHED AND RIVER - REMEDIAL OPTIONS TO BE FURTHER ASSESSED

In addition to his "retained" options, King also proposed that some options be further studied because he lacked the information to do so. In other words, King presented no meaningful case for these options at all. We agree; none of these options should be considered by the Court for that reason alone. Nonetheless, we offer some additional analysis of these options.

4.1 Localized Soil Excavation

4.1.1 Characterization

Soil excavation from pasture amended with poultry litter was suggested by King as a method to remove soil phosphorus from the IRW and reduce phosphorus runoff to surface waters. Limited soil excavation was retained by King for further consideration as an approach to consider with respect to soils that have especially high phosphorus levels.

4.1.2 Critique

King provided no support for his selection of STP 65 lb/acre as the level of soil phosphorus that would constitute "high". Given that an STP of 120 is the OSU standard to ensure sufficient nutrients for full crop yield, an STP less than 120 is not considered by experts to be "high". But in any event, the logistics and costs related to excavation of phosphorus-rich soil and replacement with lower phosphorus soils would make this technology infeasible and not implementable at the scale of the IRW (King report, page 11).

4.1.3 Missing Required Information

King admitted that soil excavation, even at a localized scale, would require additional investigations and assessments to (1) identify lands with high phosphorus concentrations that are susceptible to runoff and/or leaching; (2) identify phosphorus loadings to groundwater and surface water associated with identified areas; (3) estimate phosphorus reductions and costs; and (4) compare soil excavation to other technologies to determine relative benefits. (King Report, pages 11-12). Furthermore, an assessment of the locations that would be candidates for localized extraction, how the extraction would be performed, and potential environmental risks would be needed prior to the determination of the efficacy of soil excavation as a phosphorus removal method in the IRW. A determination of how a non-party (i.e., a grower no longer operating or may have moved out of the IRW entirely) would comply with a remedy has not been determined or suggested. Furthermore, the STP level that would be considered "high" would need to be determined prior to the process of identifying which localized soils would be excavated. Lastly, analysis would be required to confirm that the "high" STP levels result from the activities of the Defendants and are tied to alleged harm caused by the Defendants. The State has failed to conduct the work that would have been needed to identify what soil, if any, needs to be remedied. At the present time, the viability of this approach is not known. As such, this proposed remedy is not available.

4.2 Alum Application to Fields

4.2.1 Characterization

Field application of aluminum sulfate (alum) was suggested by King as a method to reduce phosphorus runoff to surface waters. King suggested that alum might be added to land where poultry waste has been applied, and excess phosphorus persists. (King report, page 12).

4.2.2 Critique

King failed to identify any locations where field application of alum has been done. Although in-house alum amended poultry litter applications to fields may reduce the potential for phosphorus in field runoff (Moore 1999), there seems to be no prior use cases of alum application directly to fields for the purpose of reducing phosphorus runoff to surface waters. Furthermore, although alum application directly to fields has apparently not been used for this purpose, it may be that the amount of alum that would be applied would be substantially more than what is used for in-house poultry litter amendment. Significant quantities of alum applied to fields in the IRW, particularly at the watershed scale, has the potential to increase the risk of aluminum toxicity to aquatic biota in streams. This requires consideration of the potential adverse ecological effects. Furthermore, landowners may object to spreading alum directly on their lands.

4.2.3 Missing Required Information

Given the apparent lack of documented use cases or studies related to the efficacy of alum application to fields as a method for reducing phosphorus runoff to surface water, this suggested treatment technology would require effort to document effectiveness and safety. Without precedent for the use of this proposed remedy, an assessment to document effectiveness would have been needed, but has not been provided. Furthermore, the locations of the IRW at which alum application to fields may address conditions associated with the activities of the Defendants have not been identified. The risk of biological and ecological harm stemming from the introduction of aluminum to soils and subsequent transport to surface waters of the IRW would also be needed for this proposed soil phosphorus treatment technology to be considered available for use. No determination has been made with respect to who would pay for the alum material and for the effort involved with field application, nor the environmental monitoring that would be needed to ensure health and safety. Given that this remedy has not been previously documented nor has an assessment of potential effectiveness or viability been performed, this remedy is not available.

4.3 Crop and Nutrient Management with Nitrogen Supplementation

4.3.1 Characterization

Crop and nutrient management with nitrogen supplementation was suggested by King as a method to treat watershed soil phosphorus in the IRW and reduce phosphorus runoff to surface waters. King stated that crop production and removal from lands where poultry waste has been applied is a technology that may potentially be used to reduce the amount of phosphorus in the soil. Crops would need to be fertilized with nitrogen from a source with little or no phosphorus content.

Harvested crops would then be shipped out of the IRW, thereby reducing the phosphorus mass within the IRW. (King Report, page 13).

4.3.2 Critique

This type of nutrient management activity is an example of what may be prescribed in an individual nutrient management plan for a given agricultural operation. Potential application at the watershed scale would entail considerable uncertainty and does not appear to be warranted.

Utilization of inorganic fertilizer would create a need for regulations around its use to avoid unintended consequences related to eutrophication effects caused by mobile nitrate leaching. If such a BMP was considered useful for a given parcel, implementation of such a BMP (i.e., crop and nutrient management with inorganic N-based fertilizer) would be specified in a nutrient management plan designed for a given land area based on site conditions.

Although phosphorus removal rates could potentially be increased through crop and nutrient management with nitrogen supplementation, this can result in deficiency of other required plant nutrients (e.g., potassium, calcium). As such, careful consideration of the availability of all essential plant nutrients would be needed when using this practice as a management strategy to reduce soil phosphorus levels. Given the diversity of land use history, farming practices, and site conditions within the IRW, watershed scale implementation of crop and nutrient management with nitrogen supplementation would not be advisable. However, this type of nutrient management activity may be prescribed in an individual nutrient management plan developed for an individual pasture located in the IRW. Furthermore, the potential quantities of phosphorus removed and associated reduction in phosphorus loading to IRW surface waters has not been quantified.

There is substantial risk of eutrophication of streams in the IRW when inorganic nitrogen is introduced to the system. Nitrogen is more mobile in the watershed than phosphorus. Thus, adding nitrogen can increase the eutrophication of the adjacent stream water. Although freshwater systems such as the IRW surface waters are largely phosphorus-limited, nitrogen can still play a role in nutrient limitation. Co-limitation between nitrogen and phosphorus is common. Implementation of crop and nutrient management with nitrogen supplementation throughout the IRW would be reckless and very likely damaging given that inorganic nitrogen can more easily leach to surface waters causing eutrophication. Crop and nutrient management with nitrogen supplementation is already a candidate BMP for prescription in an individual nutrient management plan developed for a given pasture located in the IRW. Thus, this strategy is currently in use for the types of locations and circumstances where it can be implemented in an appropriate manner.

4.3.3 Missing Required Information

King stated that, due to (1) the time frame for implementation; (2) unknown effectiveness of this technology in the short term for removing phosphorus from soil; and (3) uncertainties associated with reductions in phosphorus loading to groundwater, streams, rivers and Lake Tenkiller, this technology would require additional investigation and assessment (King Report; page 13). This

would be needed prior to consideration of this remedy as available for treatment. Furthermore, given the possibility of watershed scale use of inorganic fertilizer to cause eutrophication effects caused by mobile nitrate leaching, an assessment of this potential and possibility for regulating the use of inorganic fertilizer would be needed prior to considering this remedy as available.

4.4 Stream Bank stabilization

4.4.1 Characterization

King suggested that stream bank stabilization could offer a method to address erosion and phosphorus transport to surface waters of the IRW. Stream and riverbank stabilization can reduce erosion of bank soils into surface waters. A variety of techniques can stabilize banks, ranging from "hard" stabilization using rock or gabions to "soft" stabilization using natural vegetation, plantings or "biologs" (natural materials such as coconut husks woven into the shape of a log).

4.4.2 Critique

King concluded that stream bank stabilization is expected to be largely ineffective at reducing phosphorus in surface waters of the IRW, stating that this technology would not substantially reduce soluble phosphorus transport to stream water. In King's view, bank erosion is not considered to be a substantial contributor to overall phosphorus loading to the rivers and streams of IRW and Lake Tenkiller, but King offers no analysis to support that view. (King Report, page 15). Erosion does seem to be a meaningful contributor of phosphorus loading. (Connolly 2024).[10]

Widespread use of bank stabilization as a remedy would be expensive and would be of limited value in reducing phosphorus transport. It would also cause harm to the stream morphology. Streams meander. Bank stabilization interferes with natural hydrological processes. Furthermore, bank stabilization projects require the consent and cooperation of riparian property owners, who are not parties to this lawsuit.

4.4.3 Missing Required Information

Given that stream bank stabilization along all stream lengths is not possible or desirable, an analysis would be needed of which stream lengths should be provided with bank stabilization because they are contributing to injury. However, there has been no determination of the existence, extent, or location of such stream lengths. Lastly, any bank stabilization efforts ordered as a remedy in this suit would need be demonstrated to be remedying circumstances attributable to the conduct of the Defendants, as opposed to phosphorus from other sources being released through natural or human-caused erosion. Given that a remedy is only available if it addresses the purported injury, stream bank stabilization cannot be considered a remedy because the locations of the theorized sources of the injury have not been identified.

[10] *Illinois River and Tributaries Streambank Erosion Sites and Analysis 2020 Report*, Natural State Streams LLC.

4.5 Constructed Wetland

4.5.1 Characterization

Construction of wetland areas was suggested by King as a method to treat riverine phosphorus in the IRW. Wetlands can be constructed to capture sediments and nutrients from surface water runoff. The conditions required for a constructed wetland to be effective in removing sediments and nutrients include flat topography, stable hydrology, suitable substrate, maintenance and periodic removal of accumulated sediment and suitable plantings. For effectiveness in phosphorus removal, wetland loadings should generally be less than about one gram of phosphorus per square meter per year (Richardson and Qian, 1999). (King Report, page 15)

4.5.2 Critique

The IRW is characterized by significant topographic relief. The Springfield Plateau occupies the northern two-thirds of the IRW. It consists of gently undulating to steeply rolling topography. The Boston Mountains are the highest of the plateaus in the Ozarks. They form the southern portion of the IRW. Local relief in some places exceeds 1,500 feet, and the southern portion is characterized by greater slopes and overall ruggedness. There is very little flat land in the IRW. (Findings, p. 6-7)

Given that wetland areas occur on relatively low-lying and flat areas of land, the topography of the IRW is not conducive to widespread expansion of natural wetlands. According to the National Wetland Inventory, freshwater wetlands (emergent and forested/shrub) not directly linked with a river or lake comprise less than 1% of the IRW (less than 10,000 acres), most of which are situated near higher order streams. Few opportunities for significantly sized constructed wetlands exist in the IRW.

Based on Kadlec et al. (2016) and an assumed wetland phosphorus removal rate of approximately 9 lb/acre/year (i.e., approximately 1 $g/m^2/yr$; Richardson and Qian, 1999), approximately 12,000 acres of wetland would be needed to remove 50,000 kg of phosphorus annually. This estimated extent of wetland treatment area is roughly the size of the surface area of Tenkiller Lake and would constitute more than a doubling of the area of existing wetland in the IRW. Given that much of the area conducive to wetlands already exists as wetlands (i.e., pre-existing wetlands are not candidates for restoration), constructed wetlands do not provide viable remedy.

4.5.3 Missing Required Information

A detailed analysis of possible locations for constructed wetlands would be needed prior to consideration of constructed wetlands as viable. Furthermore, a realistic determination would be needed of the possibility for acquisition of the land that would be required for wetland construction on these theoretical land areas. All of this information would be required prior to consideration of constructed wetlands as an available remedy.

5 TENKILLER LAKE - REMEDIAL OPTIONS TO BE FURTHER ASSESSED

King proposed three possible engineering solutions to address eutrophication of Tenkiller Lake: sediment removal (dredging), alum application to the lake, and layered aeration. Each of these has been used elsewhere, but mostly in relatively small and shallow lakes. Tenkiller Lake is a deep and large lake (King Deposition, page 55). The feasibility for treating lakes as large and deep as Tenkiller Lake is questionable. King did not cite any comparable examples where this has been done. The modifications to the Tenkiller Lake impoundment suggested by King are seemingly unprecedented. Recommendations regarding a path forward with respect to management of the reservoir would require a very substantial undertaking and inclusion of the U.S. Army Corps of Engineers, among a variety of other stakeholders. Following those recommendations, a detailed and comprehensive evaluation of the proposed management alternatives would be needed.

Defendant's expert Dr. Connolly pointed out that by using only data from the lacustrine portion of the lake, Tenkiller Lake in most cases would qualify as mesotrophic. This calls into question the purported need to undertake a major restoration effort.

Field and Stream magazine deemed Tenkiller Lake one of the top 10 fisheries in the US (June 13, 2004). More recently, *Field and Stream* included a new list of top fishing lakes (https://bit.ly/40SjJaR). They selected one lake per state (n = 50). Tenkiller Lake was selected as the featured lake for Oklahoma. If Tenkiller Lake has such robust fishery resource, it seems inappropriate to try to fix, using an engineering solution, something that may not be broken.

King (Trial Transcript, page 8073) did not have a definitive proposal to recommend to the court of any steps to be taken directly on Tenkiller Lake. King (Deposition, page 166) agreed that he was not in a position to provide a definitive recommendation or proposal regarding remediation efforts focused on the lake.

King (Trial Transcript, page 8113) did not discuss how his recommendations would deal with the jurisdiction of various federal and state agencies. These would include the Oklahoma Water Resources Board; the Oklahoma Department of Agriculture, Food and Forestry; the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the Oklahoma Department of Environmental Quality, or any of the state agencies in Arkansas.

5.1 Sediment Removal

5.1.1 Characterization

Lake sediment removal was suggested by King as a method to address phosphorus loading to Tenkiller Lake. This action would require transportation and disposal of dredged spoils in a facility designed to prevent reintroduction of phosphorus into surface water or groundwater (King Report, page 17).

Dredging involves removing sediment from the bottom of a lake, typically through mechanical or hydraulic methods. An assessment of sediment characteristics is developed prior to determination

of the most appropriate dredging method. Dredging equipment mobilized to the lake area extracts (e.g., through excavation or suction methods) sediments which are transported to a designated disposal site (e.g., landfill). Water quality monitoring during the dredging process is required to document the extent to which operations may cause exceedance of water quality standards, which can result in curtailment of dredging activities and/or biological harm.

5.1.2 Critique

Although dredging can reduce phosphorus levels in a lake, it can be costly, particularly for large projects. Given the size and depth of Tenkiller Lake, dredging its sediment would be prohibitively difficult and expensive.

Riza et al. (2023) reviewed the effectiveness and environmental impacts of dredging to address lake eutrophication. Case studies included in this review (n = 13) showed that dredging was sometimes effective at controlling lake eutrophication. However, average reported lake depth was dramatically shallower among these case studies, as compared with Tenkiller Lake, with lakes ranging between 1.1 and 2.5 meters in depth. The average depth of Tenkiller Lake (50 meters) is more than 27 times the midpoint of this range (1.8 meters) of depths reported in Riza et al. (2023).

Dredging lake sediments to reduce the amount of phosphorus resuspension from sediment to water columns can be effective in small, shallow lakes. In some cases, the degree of eutrophication remained high, and there was no evident reduction in internal loading (Riza et al. 2023). Tenkiller Lake is likely too large and too deep for dredging to be practical.

Dredging any lake will be disruptive to the lake ecosystem. Sediments become resuspended in the lake while dredging. They can then be transported downstream causing potential perturbations for downstream biota. A suitable disposal site for dredged materials, which would contain potentially toxic chemicals, can be challenging. With respect to lake sediment management, the typical approach is to keep sediments in place unless a strong need for removal is identified. No such showing has been made for Tenkiller Lake.

Tenkiller Lake cannot be dredged without approval from the U.S. Army Corps of Engineers. If one wanted to do something massive, like dredging the lake, that would require preparation of an Environmental Impact Statement. It is not clear who would prepare that and what that would entail.

5.1.3 Missing Required Information

Approval by the U.S. Army Corps of Engineers would be required prior to consideration of dredging Tenkiller Lake as an available remedy. Furthermore, a detailed feasibility study related to the cost, logistics, and safety issues would be needed as well. There is no question that a detailed Environmental Impact Statement would be needed prior to consideration of dredging Tenkiller Lake as an available remedy. Further still, the extent to which dredging may be needed to reduce nutrients and algal growth in Tenkiller Lake has not been established, let alone the extent to which an injury to the lake has been caused by land application of poultry litter.

5.2 Alum Application

5.2.1 Characterization

Alum application directly to the lake was suggested by King as a method to treat phosphorus resuspension in Tenkiller Lake. Alum treatment of Tenkiller Lake could potentially reduce the internal loading of phosphorus from lake sediments. (King Report, page 19)

The application of alum to lake water removes phosphorus through formation and precipitation of a particulate “floc” that falls out of suspension to lake sediments. It is expected that this settled floc creates a barrier that minimizes sediment phosphorus release.

5.2.2 Critique

Alum cannot be added to Tenkiller Lake without approval from the U.S. Army Corps of Engineers and preparation of an Environmental Impact Statement. There are some risks. Alum can adversely affect aquatic biota. Alum can be toxic to aquatic life at low pH (Cooke et al., 2005). (King report, page 19). Furthermore, aluminum in solution has been linked to Alzheimer’s disease in humans, although the linkage is not fully understood. Nevertheless, an effort to add aluminum to Tenkiller Lake might be met with fierce public disapproval and concern. Although the North American Lake Management Society suggests that alum can be a safe and effective lake management tool, they also acknowledge that alum applications can be toxic. Alum applications should be designed and controlled to avoid concerns with toxicity to aquatic life. (www.nalms.org)

Dissolved inorganic monomeric aluminum includes a form (Al^{3+}) that is toxic to aquatic biota and is generally not present in appreciable amounts in the environment at pH values above about 6. However, watershed amendment with alum could result in formation of aluminum hydroxide species Al(OH) and $Al(OH)_2$ in solution which are not directly toxic; but, at higher pH (above 6) these hydroxide species convert to $Al(OH)_3$. Formation of $Al(OH)_3$ creates especially toxic conditions because $Al(OH)_3$ is a solid, not dissolved. These solid particles drop out of solution and can stick to fish gills and fish egg membranes, and inhibit respiration (thereby smothering the fish or egg). This formation of $Al(OH)_3$ occurs when water pH increases, as it does in and near Tenkiller Lake. Thus, formation of aluminum hydroxide species from Al^{3+} can harm fish (Wilson and Wood 1992; Playle and Wood 1989; Exley et al. 1991). Alum application to Tenkiller Lake, particularly at the whole-lake scale, has the potential to increase the risk of aluminum toxicity to aquatic biota. Lake recreationists may object to the use of alum application to Tenkiller Lake. Careful consideration of the potential adverse ecological effects of alum application is needed.

5.2.3 Missing Required Information

Prior to considering this approach, it must first be demonstrated conclusively, based on current data, that phosphorus resuspension is occurring and causing environmental injury. Moreover, approval by the U.S. Army Corps of Engineers would be required prior to consideration of alum application to Tenkiller Lake as an available remedy. Furthermore, a detailed feasibility study

related to the cost, logistics, and safety issues would be needed as well. There is no question that a detailed Environmental Impact Statement would be needed to prior to consideration of alum application to Tenkiller Lake as an available remedy. Further still, the extent to which alum application may be needed to change the trophic status of Tenkiller Lake has not been established, let alone the extent to which an injury to the lake has been caused by land application of poultry litter.

5.3 Layered Aeration

5.3.1 Characterization

Layered aeration (also known as "layer aeration") was suggested by King as a method to increase dissolved oxygen levels that have been purported to have been depleted by algal growth and subsequent die-off from phosphorus loading to Tenkiller Lake. Layered aeration is a technique that manages oxygen levels and water quality in lakes by creating a controlled, isothermal layer within the water column. Layered aeration blends water from warm, oxygen-rich and cold, oxygen-poor depths, creating an intermediate-depth isothermal zone that supports respiratory oxygen demand in colder waters via water oxygenated through photosynthesis. Layered aeration has been used for maintaining aerobic habitat for fish and reducing phosphorus impacts on phytoplankton, as well as creating oxygenated layers at water supply reservoir intakes.

5.3.2 Critique

Lake aeration is generally associated with relatively shallow lakes, with 45 of the aerated lakes reviewed in Tammeorg (2020) having a mean average depth of 9.3 meters (SD = 14 meters), as compared with the average depth of 50 meters for Tenkiller Lake. Tammeorg et al. (2017) found that anoxia-generated phosphorus release to the hypolimnion is of minor importance in lake water quality management. The literature review conducted by Tammeorg (2020) identified an increasing number of studies reporting minimal effectiveness of improving hypolimnetic oxygen conditions.

Defendant's expert Dr. Connolly pointed out that by using only data from the lacustrine portion of the lake, Tenkiller Lake in most cases would qualify as mesotrophic. King did not provide data supporting the need for layered aeration in Tenkiller Lake. Only a few dissolved oxygen monitoring locations are available to evaluate the extent of suitable habitat for fish in Tenkiller Lake. However, the lake supports a vibrant fishery for both cold and warm water fish, suggesting that the volume of the lake with oxygen conditions suitable for fish growth and survival is not limiting a robust fishery in the lake. As such, layered aeration in Tenkiller Lake seems to be of little ecological relevance.

Layered aeration within Tenkiller Lake cannot be implemented without approval from the U.S. Army Corps of Engineers and preparation of an Environmental Impact Statement. It is not clear who would prepare that and what that would entail.

5.3.3 Missing Required Information

Approval by the U.S. Army Corps of Engineers would be required prior to consideration of layered aeration of Tenkiller Lake as an available remedy. Furthermore, a detailed feasibility study related to the cost, logistics, and safety issues would be needed as well. There is no question that a detailed Environmental Impact Statement would be needed to prior to consideration of layered aeration of Tenkiller Lake as an available remedy. Further still, the extent to which layered aeration may be needed to support the fishery of Tenkiller Lake has not been established, let alone the extent to which an injury to the lake has been caused by land application of poultry litter.

6 SOIL TEST PHOSPHORUS RECORDS

Soil test phosphorus (STP) results are used in the development of nutrient management plans for IRW growers. The agronomic critical level for phosphorus in soils of the IRW has been represented as 65 lbs/acre. However, a field measuring 65 STP will exhibit significant variability, with different portions measuring higher or lower. Runoff and erosion are best controlled from fields with full vegetative cover; areas with fewer plants and weaker root systems are more likely to exhibit erosion and runoff. Accordingly, Oklahoma State University recommends a target level of 120 STP to account for variability across a pasture to ensure that soil phosphorus levels are sufficient for full crop yield. At trial, State's expert Gordon Johnson agreed, noting that a field STP of 120 lbs/acre (based on an average of 15 to 20 cores per field) can be used to help ensure that 95 percent of the area of a field has sufficient phosphorus to prevent localized deficiencies for vegetation due to variability in soil phosphorus levels.

Although numerous STP results have been compiled (Doc. 2873-1), these records represent stand-alone reports and are not connected to the overall environmental context (e.g., proximity to stream and/or steep slopes), compliance with an NMP, existing fencing, presence of livestock, or history of land application of poultry litter at a given location. This submission was constrained to reports with STP values above 65. The extent to which these reports are representative of STP conditions of the IRW is unknown. The extent to which cessation of land applied poultry litter throughout the IRW would result in reduced phosphorus runoff to surface waters of the IRW has not been shown. These STP reports do not provide a sound basis for the election of an efficacious remedy or the conclusion that any such pasture has or is contributing to any harm to the IRW water resources. Nor do these reports demonstrate that an NMP or law was violated to cause that result.

7 CONCLUSION

Nutrient management and other anthropogenic activities and circumstances in the IRW have changed dramatically since 2008. Over the past 20+ years, the human population of the IRW has increased significantly, bringing with it land use changes, that in many cases have converted forest, farm, and pasture lands into commercial and residential developments. There has been an increased demand for treatment of municipal wastewater, which has taken the form of additional publicly owned treatment works coming on line, and increased flows discharging phosphorus to IRW streams and rivers. Nutrient and watershed management have also advanced considerably over this period. The two states have embraced a cooperative approach to promulgating and implementing

comprehensive watershed management plans, and assessment of water quality criteria. Correspondingly, comprehensive improvements have been made with establishment of a robust framework for managing poultry litter. Important changes have included:

- Increased adoption and implementation of state-approved nutrient management plans
- Decreased land application of poultry litter
- Increased export of poultry litter to outside the IRW
- Increased provision of poultry litter management resources to poultry growers and litter applicators
- Increased education and awareness related to the manner in which non-point source pollution originates and management practices to prevent nutrient runoff
- Establishment of conservation partnerships and implementation of best management practices

The robust nature of these watershed-wide comprehensive improvements is evidenced by the significant progress towards meeting the 0.035 mg/L total phosphorus standard for the Illinois River (Connolly 2024).

As explained by Dr. John Connolly in his report (Connelly 2024), water quality in the IRW is controlled primarily by point sources. No remedies have been proposed by the State to address phosphorus runoff from urban areas or other human sources of phosphorus. Urbanization and human population have increased dramatically in the headwaters of the IRW, with increased runoff of sediments and nutrients. These are significant contributors of point and non-point source pollution. Any remedy considered for addressing phosphorus levels in the IRW should make careful consideration of these urban sources of phosphorus. Typical remedies related to addressing phosphorus loading from urban areas would include:

- Improvement of turf management in both municipal and residential contexts (reduce grass clippings, sediment, and/or transport to sewers)
- Lawn fertilizer management
- Reduced fertilizer needs through natural lawn care and planting native vegetation
- Covering exposed soil with grass or native vegetation to limit particulate transport
- Street sweeping to remove phosphorus-containing soil and debris

- Management of pet waste
- Wastewater treatment plant upgrades
- Septic system replacement

The State of Oklahoma and State of Arkansas have committed to making improvements to water quality by addressing both point and non-point source pollution through a Memorandum of Agreement based on comprehensive EPA-approved Watershed Management Plans. This type of cooperation and coordination among state and federal entities and stakeholders is the foundation for sustainable transboundary watershed management. The goals of this process should be allowed to move forward productively and unimpeded. This will require participation among all stakeholders in the Illinois River Watershed.

REFERENCES CITED

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. Restoration and Management of Lakes and Reservoirs. 3rd Edition. CRC Press, Taylor & Francis Group, Boca Raton. 591 pp.

Exley, C., J.S. Chappell, and J.D. Birchall. 1991. A mechanism for acute aluminum toxicity in fish. Journal of Theoretical Biology 151:417-428.

FTN Associates, Ltd. 2012. Watershed-Based Management Plan for the Upper Illinois River Watershed, Northwest Arkansas. Report prepared for Illinois River Watershed Partnership and Arkansas Natural Resources Commission.

Harrison, S. 2023. The Value of Poultry Litter to Farmers on Delmarva. Master of Agricultural and Life Sciences, Environmental Science, Virginia Polytechnic Institute and State University.

King, T.W. 2008. Identification and Evaluation of Viable Remediation Alternatives to Address Injuries Related to Land Disposal of Poultry Waste within the Illinois River Watershed. Confidential Attorney Work Product.

Miles, D.M., S.L. Branton, and B.D. Lott. 2004. Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poultry Science 83:1650-1654.

Moore, P.A., T.C. Daniel, and D.R. Edwards. 1999. Reducing phosphorus runoff and improving poultry production with alum. Poultry Science 78:692-698.

Playle, R.C. and C.M. Wood. 1989. Water pH and aluminum chemistry in the gill micro-environment of rainbow trout during acid and aluminum exposures. Journal of Comparative Physiology B 159:539-550.

Richardson, R.J. and S.S. Qian. 1999. Long-term phosphorus assimilative capacity in freshwater wetlands: a new paradigm for sustaining ecosystem structure and function. Environmental Science and Technology 33:1545-1551.

Riza, M., M.N. Ehsan, M.N. Pervez, M.M.O. Khyum, Y. Cai, and V. Naddeo. 2023. Control of eutrophication in aquatic ecosystems by sustainable dredging: Effectiveness, environmental impacts, and implications. Case Studies in Chemical and Environmental Engineering. https://doi.org/10.1016/j.cscee.2023.100297.

Tammeorg, O., T. Möls, J. Niemistö, H. Holmroos, and J. Horppila. 2017. The actual role of oxygen deficit in the linkage of the water quality and benthic phosphorus release: potential implications for lake restoration. Science of the Total Environment 599:732-738.

Tammeorg, O., G. Nürnberg, J. Niemistö, M. Haldna, and J. Horppila. 2020. Internal phosphorus loading due to sediment anoxia in shallow areas: implications for lake aeration treatments. Aquatic Sciences. https://doi.org/10.1007/s00027-020-00724-0.

Water Environment Federation and American Society of Civil Engineers (WEF/ASCE). 1998. Urban Runoff Quality Management. WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87, Alexandria, VA and Reston, VA.

Wilson, R.W. and C.M. Wood. 2012. Swimming performance, whole body ions, and gill Al accumulation during acclimation to sublethal aluminium in juvenile rainbow trout *(Oncorhynchus mykiss*). Fish Physiology and Biochemistry 10(2):149-159.

ATTACHMENTS

Attachment A – CV of Timothy J. Sullivan

TIMOTHY J. SULLIVAN

EDUCATION

Ph.D. Biological Sciences/Environmental Chemistry, Oregon State University - 1983

M.A. Biological Sciences, Western State College of Colorado - 1977

B.A. History, Stonehill College - 1972

CURRENT POSITION

Past President, E&S Environmental Chemistry, Inc. Dr. Sullivan co-founded this scientific research and consulting corporation in September, 1988.

Past President, E&S Environmental Restoration, Inc. Dr. Sullivan founded this environmental restoration corporation in June, 1996.

EXPERIENCE

Dr. Sullivan is Principal Scientist Emeritus of E&S Environmental Chemistry, Inc. He has over 45 years of professional experience, including over 30 years of environmental project management experience. His expertise includes the effects of air pollution on aquatic and terrestrial resources; watershed analysis; nitrogen cycling; aquatic acid/base chemistry; mobilization, speciation and toxicity of metals in acidic waters; episodic processes controlling surface water chemistry; and environmental assessment. He is author of the National Acid Precipitation Assessment Program (NAPAP) State of Science and Technology Report on past changes in surface water acid/base chemistry throughout the United States from acid deposition. In recent years, he has also been principal investigator for a comparison between paleolimnological reconstructions of lakewater acid/base chemistry and process-based model reconstructions (U.S. Department of Energy), incorporation of an organic acid submodel into the watershed model MAGIC and testing of the revised model using data from ecosystem manipulation experiments in Norway and the U.S. (U.S. Department of Energy), investigation of the role of land use and landscape in the acidification of surface waters (U.S. Department of Energy), an analysis of the feasibility of adopting standards for deposition of nitrogen and sulfur (U.S. EPA), and a variety of nonpoint source pollution studies in forest/agricultural watersheds. His research and project management experience includes the following:

- Served as Co-PI of Diatom Paleolimnology Data Cooperative, housed at the Academy of Natural Sciences in Philadelphia and funded by NOAA and NSF. This data cooperative disseminates lake sediment core paleolimnological data focused on past climate reconstructions to the climate modeling and research community (http://diatom.acnatsci.org/dpdc/).
- Served as project manager for preparation of an Air Quality Review for Class I national parks throughout California. Also co-authored similar reviews for the Pacific

Northwest and the Rocky Mountain and Great Plains regions of the National Park Service.
- Coordinated and analyzed available data bases throughout the United States, and internationally, providing evidence regarding the extent and magnitude of surface water acidification. Summarized and synthesized pertinent data and authored the State of Science and Technology Report for the National Acid Precipitation Assessment Program (NAPAP) on historical acidification.
- Served as project manager for a modeling project to assess aquatic and terrestrial effects of air pollutants throughout the southern Appalachian Mountains for the Southern Appalachian Mountain Initiative (SAMI).
- Served as lead author and individual responsible for synthesis and integration for report to the National Park Service on the sensitivity of natural resources in Shenandoah National Park to air pollution degradation.
- Coordinated research efforts of a team of experts in the fields of surface water chemistry, mathematical modeling, and paleoecology for the purpose of comparing paleoecological inferences and process-based model hindcasts of Adirondack Mountain lakewater chemistry.
- Directed field research project for the Alaska Department of Environmental Conservation on the Kenai Peninsula to investigate forest effects from industrial emissions of nitrogen. Coordinated and supervised all logistics and field sampling activities, including aerial infrared photography, measurements of forest growth and health, and collection of soil solution, conifer needles, precipitation, and throughfall. Directed data base construction, QA, data analyses, and interpretation; served as lead author on final report.
- Served as member of NAPAP's working group that prepared the aquatic portions of the 1990 Integrated Assessment (IA), NAPAP's final policy document for Congress. Drafted major portions of the IA; participated in a series of assessment meetings attended by federal, national laboratory and industry scientists, economists, and policy specialists; provided input on all aquatics sections of the final document. Also authored the aquatic sections of NAPAP’s 1996 Report to Congress.
- Served as project manager for the Tillamook Bay National Estuary Project for several water quality monitoring projects to evaluate the concentrations and loads of nutrients, sediment, and fecal coliform bacteria in the five rivers that flow into Tillamook Bay, Oregon. These projects included long-term monitoring, storm monitoring, source area identification, and evaluation of the relationships between land use and water quality.
- Served as project manager for E&S’s role in the construction and management of a diatom paleoclimate data cooperative for North and South America. The data cooperative brought together paleolimnological data from a multitude of sources that can be used to reconstruct aspects of historical regional climates from diatom remains in dated lake sediment cores.

AWARDS AND HONORS

Academic scholarship, Stonehill College, 1968-72
Massachusetts State Scholarship, 1969-72
Cum laude, Stonehill College, 1972

Postdoctoral fellowship, Royal Norwegian Council for Scientific and Industrial Research, 1984-86
Director's Technical Contribution Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1987
Northrop Services, Inc., Best Orator, Effective Winning Presentations, 1987
Best Scientific Paper Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1988

PUBLICATIONS

Books, Special Issues

Sullivan, T.J. 2005. Acidification - chronic. In: Lehr, J.H. and J. Keeley (Eds.). Water Encyclopedia: Surface and Agricultural Water. John Wiley & Sons.

Sullivan, T.J. 2000. Aquatic Effects of Acidic Deposition. Lewis Publ., Boca Raton, FL. 373 pp.

Seip, H.M., L. Pawlowski, and **T.J. Sullivan** (eds.). 1994. Environmental degradation due to heavy metals and acidifying deposition - A Polish-Scandinavian Workshop. Ecol. Engr. Special Issue. 3(3):205-314.

Pawlowski, L., H.M. Seip, and **T.J. Sullivan** (eds.). 1994. Aluminum in the environment. J. Ecol. Chem. 3(3).

Sullivan, T.J. and C. Moersch. 1993. Radon Alert (Teacher Guides for Junior High School Education). E&S Geographic and Information Services, Corvallis, OR. 2 vol., 204 pp.

Sullivan, T.J. and C. Moersch. 1992. Radon Alert (Teacher Guides for High School Education). E&S Geographic and Information Services, Corvallis, OR. 4 vol., 368 pp.

Sullivan, T.J. 1991. Oregon Coast Recreational Atlas. A Guide to Natural Resources and Recreational Opportunities. E&S Geographic and Information Services, Corvallis, OR. 106 pp.

NAPAP Aquatic Effects Working Group (Multiple authors including **Sullivan, T.J.**). 1991. National Acid Precipitation Assessment Program 1990 Integrated Assessment. National Acid Precipitation Assessment Program, Washington, DC. 520 pp.

Sullivan, T.J. 1990. Historical Changes in Surface Water Acid-Base Chemistry in Response to Acidic Deposition. State of the Science, SOS/T 11, National Acid Precipitation Assessment Program. 212 pp.

Journal Articles/Book Chapters

Tourville, J.C., M.R. Zarfos, G.B. Lawrence, T.C. McDonnell, **T.J. Sullivan**, and M. Dovčiak. 2023. Soil biotic and abiotic thresholds in sugar maple and American beech seedling establishment in forests of the northeastern United States. Plant Soil. 10.1007/s11104-023-06123-2.

McDonnell, T.C., J. Phelan, A.F. Talhelm, B.J. Cosby, C.T. Driscoll, **T.J. Sullivan**, and T. Greaver. 2023. Protection of forest ecosystems in the eastern United States from elevated atmospheric deposition of sulfur and nitrogen: A comparison of steady-state and dynamic model results. Environ. Pollut. 10.1016/j.envpol.2022.120887.

McDonnell, T.C., C.M. Clark, G.J. Reinds, **T.J. Sullivan**, and B. Knees. 2022. Modeled vegetation community trajectories: Effects from climate change, atmospheric nitrogen deposition, and soil acidification recovery. Environmental Advances 9:100271. 10.1016/j.envadv.2022.100271.

McDonnell, T.C., C.T. Driscoll, **T.J. Sullivan**, D.A. Burns, B.P. Baldigo, S. Shao, and G.B. Lawrence. 2021. Regional target loads of atmospheric nitrogen and sulfur deposition for the protection of stream and watershed soil resources of the Adirondack Mountains, USA. Environ. Pollut. 281:117110. 10.1016/j.envpol.2021.117110.

McDonnell, T.C., G.J. Reinds, G.W.W. Wamelink, P.W. Goedhart, M. Posch, **T.J. Sullivan**, and C.M. Clark. 2020. Threshold Effects of Air Pollution and Climate Change on Understory Plant Communities at Forested Sites in the Eastern United States. Environ. Pollut. 262. 10.1016/j.envpol.2020.114351.

Shao, S., C.T. Driscoll, **T.J. Sullivan**, D.A. Burns, B.P. Baldigo, G.B. Lawrence, and T.C. McDonnell. 2020. The response of stream ecosystems in the Adirondack region of New York to historical and future changes in atmospheric deposition of sulfur and nitrogen. Sci. Total Environ. doi:org/10.1016/j.scitotenv.2020.137113.

Burns, D.A., T.C. McDonnell, K.C. Rice, G.B. Lawrence, and **T.J. Sullivan**. 2020. Chronic and episodic acidification of streams along the Appalachian Trail corridor, eastern United States. Hydrol. Process. 10.1002/hyp.13668 34:1498-1513.

Zarfos, M.R., M. Dovciak, G.B. Lawrence, T.C. McDonnell, and **T.J. Sullivan**. 2019. Plant richness and composition in hardwood forest understories vary along an acidic deposition and soil-chemical gradient in the northeastern United States. Plant Soil. 10.1007/s11104-019-04031-y

McDonnell, T.C., S. Belyazid, **T.J. Sullivan**, M. Bell, C. Clark, T. Blett, T. Evans, W. Cass, A. Hyduke, and H. Sverdrup. 2018. Vegetation dynamics associated with changes in atmospheric nitrogen deposition and climate in hardwood forests of Shenandoah and Great Smoky Mountains national parks, USA. Environ. Pollut. 237:662-674. 10.1016/j.envpol.2018.01.112.

McDonnell, T.C., G.J. Reinds, **T.J. Sullivan**, C.M. Clark, L.T.C. Bonten, J.P. Mol-Dijkstra, G.W.W. Wamelink, and M. Dovciak. 2018. Feasibility of coupled empirical and dynamic modeling to assess climate change and air pollution impacts on temperate forest vegetation of the eastern United States. Environ. Pollut. 234:902-914. doi.org/10.1016/j.envpol.2017.12.002.

McDonnell, T.C., **T.J. Sullivan**, and C.M. Beier. 2018. Influence of climate on long-term recovery of Adirondack Mountain lakewater chemistry from atmospheric deposition of sulfur and nitrogen. Adir. J. Environ. Stud. 22:20-45.

Lawrence, G.B., T.C. McDonnell, **T.J. Sullivan**, M. Dovciak, S.W. Bailey, M.R. Antidormi, and M.R. Zarfos. 2017. Soil base saturation combines with beech bark disease to influence

composition and structure of sugar maple-beech forests in an acid rain-impacted region. Ecosystems 10.1007/s10021-017-0186-0.

McDonnell, T.C., M.R. Sloat, **T.J. Sullivan**, C.A. Dolloff, P.F. Hessburg, N.A. Povak, W.A Jackson, and C. Sams. 2015. Downstream warming and headwater acidity may diminish coldwater habitat in southern Appalachian Mountain streams. Plos One. DOI:10.1371/journal.pone.0134757.

McDonnell, T.C., **T.J. Sullivan**, P.F. Hessburg, K.M. Reynolds, N.A. Povak, B.J. Cosby, W. Jackson, and R.B. Salter. 2014. Steady-state sulfur critical loads and exceedances for protection of aquatic ecosystems in the US southern Appalachian Mountains. J. Environ. Manage. 146:407-419.

McDonnell, T.C., S. Belyazid, **T.J. Sullivan**, H. Sverdrup, W.D. Bowman, and E.M. Porter. 2014. Modeled subalpine plant community response to climate change and atmospheric nitrogen deposition in Rocky Mountain National Park, USA. Environ. Pollut. 187:55-64.

Povak, N.A., P.F. Hessburg, T.C. McDonnell, K.M. Reynolds, **T.J. Sullivan**, R.B. Salter, and B.J. Cosby. 2014. Machine learning and linear regression models to predict catchment-level base cation weathering rates across the southern Appalachian Mountain region, USA. Water Resour. Res. DOI: 10.1002/2013WR014203.

McDonnell, T.C., **T.J. Sullivan**, B.J. Cosby, W.A. Jackson, and K. Elliott. 2013. Effects of climate, land management, and sulfur deposition on soil base cation supply in national forests of the Southern Appalachian Mountains. Water Air Soil Pollut. 224:1733. DOI 10.1007/s11270-013-1733-8.

Sullivan, T.J., G.B. Lawrence, S.W. Bailey, T.C. McDonnell, C.M. Beier, K.C. Weathers, G.T. McPherson, and D.A. Bishop. 2013. Effects of acidic deposition and soil acidification on sugar maple in the Adirondack Mountains, New York. Environ. Sci. Technol. 47:12687-12694. 10.1021/es401864w.

Povak, N.A, Hessburg, P.F., Reynolds, K.M., **Sullivan, T.J.**, McDonnell, T.C., and Salter, R.B. 2013. Machine learning and hurdle models improve regional predictions of stream water acid neutralizing capacity. Water Resour. Res. doi: 10.1002/wrcr.20308.

Herlihy, A.T., J.B. Sobota, T.C. McDonnell, **T.J. Sullivan**, S. Lehmann, and E. Tarquinio. 2013. An a priori process for selecting candidate reference lakes for a national survey. Freshw. Sci. 32(2):385-396.

McDonnell, T.C., B.J. Cosby, and **T.J. Sullivan**. 2012. Regionalization of soil base cation weathering for evaluating stream water acidification in the Appalachian Mountains, USA. Environmental Pollution 162:338-344

Sullivan, T.J., B.J. Cosby, T.C. McDonnell, E. Porter, T. Blett, R. Haeuber, C.M. Huber, and J. Lynch. 2012. Critical loads of acidity to protect and restore acid-sensitive streams in Virginia and West Virginia. Water Air and Soil Pollution. 223:5759–5771. doi: 10.1007/s11270-012-1312-4.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, T.C. McDonnell, A.T. Herlihy, and D.A. Burns. 2012. Target loads of atmospheric sulfur and nitrogen deposition for protection of acid sensitive aquatic resources in the Adirondack Mountains, New York. Water Resources Research. 48: WO 1547, doi:10.1029/2011WR011171

Sverdrup, H., T.C. McDonnell, **T.J. Sullivan**, B. Nihlgård, S. Belyazid, B. Rihm, E. Porter, W.D. Bowman, and L. Geiser. 2011. Testing the feasibility of using the ForSAFE-VEG model to map the critical load of nitrogen to protect plant biodiversity in the Rocky Mountains region, USA. Water Air Soil Pollut. DOI 10.1007/s11270-011-0865-y.

Sullivan, T.J., B.J. Cosby, B. Jackson, K.U. Snyder, and A.T. Herlihy. 2011. Acidification and Prognosis for Future Recovery of Acid-Sensitive Streams in the Southern Blue Ridge Province. Water Air Soil Pollut 219:11-26.

Sullivan, T.J., B.J. Cosby, and B. Jackson. 2011. Target loads of atmospheric sulfur deposition for the protection and recovery of acid-sensitive streams in the Southern Blue Ridge Province. J. Environ. Manage. 92:2953-2960.

McDonnell, T.C., B.J. Cosby, **T.J. Sullivan**, S.G. McNulty, E.C. Cohen. 2010. Comparison among model estimates of critical loads of acidic deposition using different sources and scales of input data. Environ. Pollut. 158:2934-2939.

Sullivan, T.J., B.J. Cosby, J.R. Webb, R.L. Dennis, A.J. Bulger, F.A. Deviney Jr. 2008. Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. Environ. Monit. Assess. 137:85-99. DOI 10:1007/s10661-007-9731-1

Zhai, J., C. T. Driscoll, **T. J. Sullivan**, and B. J. Cosby. 2008. Regional application of the PnET-BGC model to assess historical acidification of Adirondack lakes. Water Resour. Res., 44, W01421, doi:10.1029/2006WR005532.

McNeil, B.E., J.M. Read, **T.J. Sullivan, T.**C. McDonnell, I. J. Fernandez, and C.T. Driscoll. 2008. The spatial pattern of nitrogen cycling in the Adirondack Park, New York. Ecol. Appl. 18:438–452.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, C.T. Driscoll, I.J. Fernandez, T.C. McDonnell, C.W. Boylen, S.A. Nierzwicki-Bauer, and K.U. Snyder. 2007. Assessment of the extent to which intensively-studied lakes are representative of the Adirondack region and response to future changes in acidic deposition. Water Air Soil Pollut. 185:279-291.

Sullivan, T.J., J.R. Webb, K.U. Snyder, A.T. Herlihy, and B.J. Cosby. 2007. Spatial distribution of acid-sensitive and acid-impacted streams in relation to watershed features in the southern Appalachian Mountains. Water Air Soil Pollut. 182:57-71.

McNulty, S.G., E.C. Cohen, J.A. Moore Meyers, **T.J. Sullivan**, and H. Li. 2007. Estimates of critical acid loads and exceedances for forest soils across the conterminous United States. Environ. Poll. 149(3):281-292.

Sullivan, T.J., I.J. Fernandez, A.T. Herlihy, C.T. Driscoll, T.C. McDonnell, N.A. Nowicki, K.U. Snyder, and J.W. Sutherland. 2006. Acid-base characteristics of soils in the Adirondack Mountains, New York. Soil Sci. Soc. Amer. J. 70:141-152.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2006. Relationship between size of vegetated buffers and transport of fecal coliform bacteria from pasturelands treated with dairy cow manure. Abstract. J. Dairy Sci. 89 (Suppl. 1): Abstract 298.

Sullivan, T.J., B.J. Cosby, K.A. Tonnessen, and D.W. Clow. 2005. Surface water acidification responses and critical loads of sulfur and nitrogen deposition in Loch Vale Watershed, Colorado. Water Resour. Res. 41:W01021, doi:10.1029/2004WR003414.

Sullivan, T.J., K. U. Snyder, E. Gilbert, J.M. Bischoff, M. Wustenberg, J. A. Moore, and D. Moore. 2005. Assessment of water quality in association with land use in the Tillamook Bay Watershed, Oregon. Water Air Soil Pollut. 161:3-23.

Sullivan, T.J., M.C. Saunders, B.L. Nash, K.A. Tonnessen, and B.J. Miller 2005. Application of a regionalized knowledge-based model for classifying the impacts of nitrogen, sulfur, and organic acids on lakewater chemistry. Knowledge Based Systems. 18(1):55-68.

Saunders, M.C., **T.J. Sullivan**, B.L. Nash, K.A. Tonnessen, and B.J. Miller. 2005. A knowledge-based approach for classifying lake water chemistry. Knowledge Based Systems. 18(1): 47-54.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, J.R. Webb, A.J. Bulger, K.U. Snyder, P.F. Brewer, E.H. Gilbert, and D.L. Moore. 2004. Regional model projections of future effects of sulfur and nitrogen deposition on streams in the southern Appalachian Mountains. Water Resour. Res. 40(2), W02101 doi:10.1029/2003WR001998.

Sullivan, T.J., M. Wustenberg, J. A. Moore, K. U. Snyder, E. Gilbert, D. Moore, and E. Mallery. 2004. Riparian plantings and fencing improve water quality in Tillamook River Watershed (Oregon). Ecolog. Restor. 22(2):138-140.

Sullivan, T.J., D.F. Charles, J.A. Bernert, B. McMartin, K.B. Vaché, and J. Zehr. 1999. Relationship between landscape characteristics, history, and lakewater acidification in the Adirondack Mountains, New York. Water Air Soil Pollut. 112:407-427.

Sullivan, T.J. and B.J. Cosby. 1998. Modeling the Concentration of Aluminum in Surface Waters. Water Air Soil Pollut. 105:643-659.

Sinha, R., M.J. Small, P.F. Ryan, **T.J. Sullivan**, and B.J. Cosby. 1998. Reduced-form modeling of surface water and soil chemistry for the Tracking and Analysis Framework. Water Air Soil Pollut. 105:617-642.

Sullivan, T.J. 1997. Ecosystem manipulation experimentation as a means of testing a biogeochemical model. Environ. Mgmt. 21(1):15-21.

Sullivan, T.J., J.M. Eilers, B.J. Cosby, and K.B. Vaché. 1997. Increasing role of nitrogen in the acidification of surface waters in the Adirondack Mountains, New York. Water Air Soil Pollut. 95:313-336.

Bernert, J.A., J.M. Eilers, **T.J. Sullivan**, K.E. Freemark, and C. Ribic. 1997. A quantitative method for delineating regions: an example for the Western Corn Belt Plains Ecoregion of the USA. Environ. Mgmt. 21:405-420.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, D.F. Charles, and H.F. Hemond. 1996. Influence of organic acids on model projections of lake acidification. Water Air Soil Pollut. 91:271-282.

Sullivan, T.J., B. McMartin, and D.F. Charles. 1996. Re-examination of the role of landscape change in the acidification of lakes in the Adirondack Mountains, New York. Sci. Total Environ. 183(3):231-248.

Sullivan, T.J. and B.J. Cosby. 1995. Testing, improvement, and confirmation of a watershed model of acid-base chemistry. Water Air Soil Pollut. 85:2607-2612.

Sullivan, T.J. 1994. Progress in quantifying the role of aluminum in acidification of surface waters. J. Ecol. Chem. 3:157-168.

Sullivan, T.J. 1994. Evaluation of biogeochemical models using data from experimental ecosystem manipulations. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 344-352.

Sullivan, T.J., B.J. Cosby, S.A. Norton, D.F. Charles, R.F. Wright, and E. Gjessing. 1994. Multi-site testing and evaluations of a geochemical model of acid-base chemistry: confirmation of the MAGIC model using catchment manipulation experiments and historical diatom inferences. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 360-365.

Driscoll, C.T., M.D. Lehtinen, and **T.J. Sullivan**. 1994. Modeling the acid-base chemistry of organic solutes in Adirondack, New York, lakes. Water Resour. Res. 30:297-306.

Sullivan, T.J. and D.F. Charles. 1994. The feasibility and utility of a paleolimnology/ paleoclimate data cooperative for North America. J. Paleolimnol. 10:265-273.

Sullivan, T.J. 1993. Whole ecosystem nitrogen effects research in Europe. Environ. Sci. Technol. 27(8):1482-1486.

Sullivan, T.J., R.S. Turner, D.F. Charles, B.F. Cumming, J.P. Smol, C.L. Schofield, C.T. Driscoll, B.J. Cosby, H.J.B. Birks, A.J. Uutala, J.C. Kingston, S.S. Dixit, J.A. Bernert, P.F. Ryan, and D.R. Marmorek. 1992. Use of historical assessment for evaluation of process-based model projections of future environmental change: Lake acidification in the Adirondack Mountains, New York, U.S.A. Environ. Poll. 77:253-262.

Turner, R.S., P.F. Ryan, D.R. Marmorek, K.W. Thornton, **T.J. Sullivan**, J.P. Baker, S.W. Christensen, and M.J. Sale. 1992. Sensitivity to change for low-ANC eastern US lakes and streams and brook trout populations under alternative sulfate deposition scenarios. Environ. Poll. 77:269-277.

Sullivan, T.J. 1991. Long-term temporal trends in surface water chemistry. pp. 615-639. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Husar, R.B., **T.J. Sullivan**, and D.F. Charles. 1991. Methods for evaluation of historical change. pp. 65-82. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Eilers, J.M., **T.J. Sullivan**, and K.C. Hurley. 1990. The most dilute lake in the world? Hydrobiologia 199:1-6.

Sullivan, T.J., D.F. Charles, J.P. Smol, B.F. Cumming, A.R. Selle, D.R. Thomas, J.A. Bernert, and S.S. Dixit. 1990. Quantification of changes in lakewater chemistry in response to acidic deposition. Nature 345:54-58.

Sullivan, T.J., D.L. Kugler, M.J. Small, C.B. Johnson, D.H. Landers, B.J. Rosenbaum, W.S. Overton, W.A. Kretser, and J. Gallagher. 1990. Variation in Adirondack, New York, lakewater chemistry as a function of surface area. Water Resour. Bull. 26:167-176.

Seip, H.M., D.O. Anderson, N. Christophersen, **T.J. Sullivan**, and R.D. Vogt. 1989. Variations in concentrations of aqueous aluminum and other chemical species during hydrological episodes at Birkenes, southernmost Norway. J. Hydrol. 108:387-405.

Johnson, C.B., **T.J. Sullivan**, and D.J. Blick. 1989. Defining regional populations of lakes for the assessment of surface water quality. Water Resour. Bull. 25:1-8.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1989. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. pp. 159-169. In: Lewis, T.E. (Ed.), Environmental Chemistry and Toxicology of Aluminum, Lewis Publishers Inc., Chelsea, MI.

Sullivan, T.J., C.T. Driscoll, S.A. Gherini, R.K. Munson, R.B. Cook, D.F. Charles, and C.P. Yatsko. 1989. The influence of organic acid anions and aqueous aluminum on measurements of acid neutralizing capacity in surface waters. Nature 338:408-410.

Sullivan, T.J., J.M. Eilers, M.R. Church, D.J. Blick, K.N. Eshleman, D.H. Landers, and M.S. DeHaan. 1988. Atmospheric wet sulfate deposition and lakewater chemistry. Nature 331:607-609.

Sullivan, T.J., C.T. Driscoll, J.M. Eilers, and D.H. Landers. 1988. Evaluation of the role of sea salt inputs in the long-term acidification of coastal New England lakes. Environ. Sci. Technol. 22:185-190.

Muniz, I.P., R. Andersen, and **T.J. Sullivan**. 1987. Physiological response of brown trout spawners and post-spawners to acidic streamwater. Water Air Soil Pollut. 36:371-379.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1987. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. Preprint extended abstract. Amer. Chem. Soc. Meeting, New Orleans, August 30-Sept. 4.

Andersen, R., Ø. Haraldstad, I.P. Muniz, and **T.J. Sullivan**. 1987. Effects of shellsand on water quality and mature brown trout. Fauna 40:150-159 (in Norwegian).

Sullivan, T.J., I.P. Muniz, and H.M. Seip. 1986. A comparison of frequently used methods for the determination of aqueous aluminum. Int. J. Environ. Anal. Chem. 26:61-75.

Sullivan, T.J., N. Christophersen, I.P. Muniz, H.M. Seip and P.D. Sullivan. 1986. Aqueous aluminum chemistry response to episodic increases in discharge. Nature 323:324-327.

Røyset, O. and **T.J. Sullivan**. 1986. Effect of dissolved humic compounds on the determination of aqueous aluminum by three spectrophotometric methods. Int. J. Environ. Anal. Chem. 27:305-14.

Sullivan, T.J. and M.C. Mix. 1985. Persistence and fate of polynuclear aromatic hydrocarbons deposited on slash burn sites in the Cascade Mountains and Coast Range of Oregon. Arch. Environ. Contam. Toxicol. 14:187-192.

Sullivan, T.J. and M.C. Mix. 1983. Pyrolytic deposition of polynuclear aromatic hydrocarbons due to slash burning on clear-cut sites. Bull. Environ. Contam. Toxicol. 31:207-215.

Sullivan, T.J. and M.C. Mix. 1983. A simple and inexpensive method for measuring integrated light energy. Environ. Sci. Technol. 17:127-128.

Sullivan, T.J. 1982. Avian species diversity: Its relation to the competition hypothesis. Proc. Oregon Acad. Sci. 18:10-20

Sullivan, T.J. 1977. Avian and mammalian distribution in the Powderhorn Primitive Area, Colorado. M.A. thesis. Western State College, Gunnison, CO. 209 pp.

Reports

Driscoll, C.T., **T.J. Sullivan**, B.P. Baldigo, D.A. Burns. S. Shao. T.C. McDonnell, and G.B. Lawrence. 2020. Responses of Streams in the Adirondack Mountains to Changes in Atmospheric Deposition of Sulfur and Nitrogen: Past and Future Acidification and Target Loads of Deposition to Promote Resource Recovery. Report Number 20-19. New York State Energy Research and Development Authority, Albany, NY.

McDonnell, T.C., **T.J. Sullivan**, P.B. Woodbury, J.L. Wightman, G.M. Domke, C.M. Beier, and C. Trettin. 2020. Sources and Sinks of Major Greenhouse Gases Associated with New York State's Natural and Working Lands: Forests, Farms, and Wetlands. Report Number 20-06. New York State Energy Research and Development Authority, Albany, NY.

McDonnell, T.C., **T.J. Sullivan**, B. Knees, M. Bell, and E. Felker-Quinn. 2020. Intermodel Comparison of Atmospheric Nitrogen Deposition Estimates for the Conterminous United States and Critical Load Exceedance for Selected National Parks. Natural Resource Report NPS/NRSS/ARD/NRR—2020/2125. National Park Service, Fort Collins, Colorado.

Lawrence, G.B., M.R. Antidormi, T.C. McDonnell, **T.J. Sullivan**, and S.W. Bailey. 2020. Adirondack New York soil chemistry data, 1992-2017. U.S. Geological Survey data release, https://doi.org/10.5066/P9YAWR0N.

McDonnell, T.C., **T.J. Sullivan**, and D.L. Moore. 2019. Critical Loads of Atmospheric Nitrogen and Sulfur Deposition for Protection of Sensitive Aquatic and Terrestrial Resources in the Intermountain Region of the USDA Forest Service. Report Prepared for the USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C., J. Aherne, **T.J. Sullivan**, C. Barton, C. Cotton, and B. Jackson. 2019. Variation in Forest Soil-Nutrient Availability: Dynamic Model Estimates of Past and Future Conditions at Two Sites in the Daniel Boone National Forest, Kentucky, USA. Report Prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C., **T.J. Sullivan**, J. Farmer, J. Rash, and W.A. Jackson. 2018. Effectiveness of Experimental Stream Liming in the Upper Santeetlah Watershed of Western North Carolina. Report Prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C., W.A. Jackson, B.J. Cosby, and **T.J. Sullivan**. 2018. Atmospheric Deposition Effects Modeling for Resource Management on Southern Appalachian National Forests. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., M.R. Zarfos, M. Dovciak, T.C. McDonnell, and G.B. Lawrence. 2018. Effects of Acid Deposition on the Biodiversity of Forest Understory Plant Communities in the Northern Hardwood Forests of the Adirondack Mountain Region. Final Technical Report 18-17. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

McDonnell, T.C., **T.J. Sullivan**, B.J. Cosby, W.A Jackson, and D.L. Moore. 2017. Estimating the Amount of Sulfur Deposition the Sipsey and Cohutta Wilderness Areas Can Tolerate While Protecting the Acid Neutralizing Capacity of Perennial Streams. Report prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

Lawrence, G.B., **T.J. Sullivan, T.**C. McDonnell, M. Dovciak, S.W. Bailey, M.R. Antidormi, and M.R. Zarfos. 2017 Soil Acidification and Beech Bark Disease: Influencing the Composition and Structure of Sugar Maple/Beech Forests. Summary Report 17-26 prepared for the New York State Energy Research and Development Authority. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., T.C. McDonnell, G.B. Lawrence, M. Dovciak, and M.R. Zarfos. 2017. Acidification and Forest Understory Plant Communities in the Adirondack Mountains. Summary Report. 17-27. New York State Energy Research and Development Authority, Albany, NY.

Sullivan, T.J., T.C. McDonnell, D.L. Moore, and M.G. Barna. 2016. Mapping of Nitrogen Critical Loads for Selected National Parks in the Western United States. Natural Resource Report NPS/NRSS/ARD/NRR—2016/1286. National Park Service, Fort Collins, Colorado.

Lawrence, G.B., **T.J. Sullivan**, D.A. Burns, S.W. Bailey, B. J. Cosby, M. Dovciak, H.A. Ewing, T.C. McDonnell, R. Minocha, R. Riemann, J. Quant , K.C. Rice, J. Siemion, K. Weathers. 2015. Acidic Deposition along the Appalachian Trail Corridor and its Effects on Acid-Sensitive Terrestrial and Aquatic Resources. Results of the Appalachian Trail MEGA-Transect Atmospheric Deposition Effects Study. Natural Resource Report NPS/NRSS/ARD/NRR—2015/996. National Park Service, Fort Collins, CO.

McDonnell, T.C. and **T.J. Sullivan**. 2014. Comparison of Regional Stream ANC Predictions for the George Washington National Forest Using Spatial and Non-Spatial Regression Modeling. Final Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C. and T. J. Sullivan. 2014. Total Atmospheric Nitrogen and Sulfur Deposition in Forest Service Wildernesses and National Forests Throughout the Conterminous United

States. Final Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, T.C. McDonnell, A.T. Herlihy, and D.A. Burns. 2014. Critical Loads of Sulfur and Nitrogen for Protection of Acid Sensitive Aquatic and Terrestrial Resources in the Adirondack Mountains. Final Report. Report No. 14-10. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, T.C. McDonnell, A.T. Herlihy, and D.A. Burns. 2014. Critical Loads of Sulfur and Nitrogen for Protection of Acid Sensitive Aquatic and Terrestrial Resources in the Adirondack Mountains. Summary Report. Report No. 14-11. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

Sullivan, T.J. and T.C. McDonnell. 2013. Mapping of Nutrient-Nitrogen Critical Loads for Selected National Parks in the Intermountain West and Great Lakes Regions. Report prepared for the National Park Service, Air Resources Division. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., G.B. Lawrence, S.W. Bailey, T.C. McDonnell, and G.T. McPherson. 2013. Effects of Acidic Deposition and Soil Acidification on Sugar Maple Trees in the Adirondack Mountains, New York. NYSERDA Report No. 13-04. New York State Energy Research and Development Authority, Albany, NY.

Sullivan, T.J. and T.C. McDonnell. 2012. Application of Critical Loads and Ecosystem Services Principles to Assessment of the Effects of Atmospheric Sulfur and Nitrogen Deposition on Acid-Sensitive Aquatic and Terrestrial Resources. Report prepared for the U.S. Environmental Protection Agency in association with Systems Research and Applications, Corp. E&S Environmental Chemistry, Inc., Corvallis, OR.

Lawrence, G.B., **T.J. Sullivan**, K.C. Weathers, B.J. Cosby, and T.C. McDonnell. 2011. Comparison of Methods for Estimating Critical loads of Acidic Deposition in the Western Adirondack Region of New York. Final Report 11-13. Prepared for the New York State Energy Research and Development Authority. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011. Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition. Natural Resource Reports NPS/NRPC/ARD/NRR—2011/349-382. National Park Service, Denver, Colorado.

Sullivan, T.J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011. Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition. Natural Resource Reports NPS/NRPC/ARD/NRR—2011/302 to 2011/334. National Park Service, Denver, Colorado.

Sullivan, T.J., B.J. Cosby, and T.C. McDonnell. 2010. Aquatic Critical Loads and Exceedances in Acid-Sensitive Portions of Virginia and West Virginia. Results of Southeastern Multiagency Critical Loads Research Project. Report prepared for National Park Service,

U.S. Environmental Protection Agency, USDA Forest Service, and U.S. Geological Survey. E&S Environmental Chemistry, Inc., Corvallis, OR.

E&S Environmental Chemistry, Inc. (including **T.J. Sullivan**). 2009. Alpine Vegetation Workshop: Response of Alpine and Subalpine Plant Species to Changes in Atmospheric N Deposition. Final Report. Held November 6-7, 2008 in Lakewood, CO. Sponsored by National Park Service and U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (**T.J. Sullivan**, contributor). 2008. Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur Ecological Criteria (Final Report). Report No. EPA/600/R-08/082F. U.S. Environmental Protection Agency, Washington, DC.

Sullivan, T.J., B.J. Cosby, K.U. Snyder, A.T. Herlihy, B. Jackson. 2007. Model-Based Assessment of the Effects of Acidic Deposition on Sensitive Watershed Resources in the National Forests of North Carolina, Tennessee, and South Carolina. Final report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., A.T. Herlihy. 2007. Air Quality Related Values and Development of Associated Protocols for Evaluation of the Effects of Atmospheric Deposition on Aquatic and Terrestrial Resources on Forest Service Lands. Final report prepared for the U.S.D.A Forest Service.

Sullivan, T.J. 2007. What's up with the Air? Shenandoah National Park. National Park Service, Luray, VA.

Sullivan, T.J., C.T. Driscoll, B.J. Cosby, I.J. Fernandez, A.T. Herlihy, J. Zhai, R. Stemberger, K.U. Snyder, J.W. Sutherland, S.A. Nierzwicki-Bauer, C.W. Boylen, T.C. McDonnell, and N.A. Nowicki. 2006. Assessment of the Extent to Which Intensively-Studied Lakes are Representative of the Adirondack Mountain Region. Final Report 06-17. New York State Energy Research and Development Authority, Albany, NY.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Lower Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Mill Creek Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Middle Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Upper Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and B.J. Cosby. 2004. Aquatic critical load development for the Monongahela National Forest, West Virginia. Report Prepared for USDA Forest Service, Monongahela National Forest, Elkins, WV. E&S Environmental Chemistry, Inc., Corvallis, OR.

Webb, J.R., **T.J. Sullivan**, and B. Jackson. 2004. Assessment of Atmospheric Deposition Effects on National Forests. Protocols for Collection of Supplemental Stream Water and Soil Composition Data for the MAGIC Model. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, J.A. Lawrence, R.L. Dennis, K. Savig, J.R. Webb, A.J. Bulger, M. Scruggs, C. Gordon, J. Ray, E.H. Lee, W.E. Hogsett, H. Wayne, D. Miller, and J.S. Kern. 2003. Assessment of Air Quality and Related Values in Shenandoah National Park. Technical Report NPS/NERCHAL/NRTR-03/090. U.S. Department of the Interior, National Park Service, Northeast Region, Philadelphia, PA.

Snyder, K.U., **T.J. Sullivan**, D.L. Moore, R.B. Raymond, and E.H. Gilbert. 2003. Trask River Watershed Analysis. Report submitted to Oregon Department of Forestry and U.S. Department of Interior, Bureau of Land Management. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and B.J. Cosby. 2002. Critical loads of sulfur deposition to protect streams within Joyce Kilmer And Shining Rock Wilderness Areas from future acidification. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., D.W. Johnson, and R. Munson. 2002. Assessment of Effects of Acid Deposition on Forest Resources in the Southern Appalachian Mountains. Report prepared for the Southern Appalachian Mountains Initiative (SAMI). E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, J.R. Webb, K.U. Snyder, A.T. Herlihy, A.J. Bulger, E.H. Gilbert, and D. Moore. 2002. Assessment of the Effects of Acidic Deposition on Aquatic Resources in the Southern Appalachian Mountains. Report prepared for the Southern Appalachian Mountains Initiative (SAMI). E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2002. Remediation of Agricultural Contributions of Fecal Coliform Bacteria, Sediment, and Heat in the Tillamook Basin: Final Report and Conclusions of the Beaver Creek Project. E&S Environmental Restoration, Inc., Corvallis, OR.

Sullivan, T.J., E.H. Gilbert, and K.U. Snyder. 2002. Results of storm-based monitoring of water quality In the Tillamook, Kilchis, Trask, and Wilson Rivers, Tillamook Basin, Oregon from 1996 to 2002. State of the Bay Report. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, D. Moore, and E. Gilbert. 2002. North Santiam River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, E. Gilbert, and D. Moore. 2002. Necanicum River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., D.L. Peterson, C.L. Blanchard, K. Savig, and D. Morse. 2001. Assessment of Air Quality and Air Pollutant Impacts in Class I National Parks of California. NPS D-1454. U.S. Dept. of the Interior, National Park Service, Air Resources Division.

Sullivan, T.J., J.M. Bischoff, K.U. Snyder, R.B. Raymond, S. White, and S.K. Binder. 2001. Wilson River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, J.M. Bischoff, S. White, and S.K. Binder. 2001. Miami River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Cosby, B.J. and **T.J. Sullivan**. 2001. Quantification of dose-response relationships and critical loads of sulfur and nitrogen for six headwater catchments in Rocky Mountain, Grand Teton, Sequoia, and Mount Rainier National Parks. Report 97-15-01. E&S Environmental Chemistry, Inc., Corvallis, OR.

Cosby, B.J. and **T.J. Sullivan**. 1999. Application of the MAGIC Model to Selected Catchments: Phase I. Southern Appalachian Mountains Initiative (SAMI). Final Report submitted to Southern Appalachian Mountains Initiative. University of Virginia, Charlottesville.

Bernert, J.A. and **T.J. Sullivan**. 1998. Bathymetric analysis of Tillamook Bay. Comparison among bathymetric databases collected in 1867,1957, and 1995. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and J.M. Eilers. 1998. River water quality monitoring plan for the Tillamook Bay National Estuary Project. Report No. 97-16-01 to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., J. M. Bischoff, K.B. Vaché, M. Wustenberg, and J. Moore. 1998. Water quality monitoring in the Tillamook Watershed. Results of a one-year periodic monitoring and storm sampling program. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., J.M. Bischoff, and K.B. Vaché. 1998. Results of storm sampling in the Tillamook Bay Watershed. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, and J.M. Eilers. 1998. Model evaluation of dose/response relationships and critical loads for nitrogen and sulfur deposition to the watersheds of Lower Saddlebag and White Dome Lakes. Report No. 97-10-01 to U.S.D.A. Forest Service. E&S Environmental Chemistry, Inc.

Peterson, D.L., **T.J. Sullivan**, J.M. Eilers, S. Brace, D. Horner, and K. Savig. 1998. Assessment of Air Quality and Air Pollutant Impacts in National Parks of the Rocky Mountains and Northern Great Plains. NPS D-657. U.S. Dept. of the Interior, National Park Service, Air Resources Division.

Bernert, J.A. and **T.J. Sullivan**. 1997. Quality Assurance Plan for the Tillamook Bay National Estuary Program. River Water Quality Monitoring Project. Report Number 96-20-01. E&S Environmental Chemistry, Inc.

Bloyd, C., J. Camp, G. Conzelmann, J. Formento, J. Molburg, J. Shannon, M. Henrion, R. Sonnenblick, K. Soo Hoo, J. Kalagnanam, S. Siegel, R. Sinha, M. Small, **T. Sullivan**, R. Marricio, P. Ryan, R. Turner, D. Austin, D. Burtraw, D. Farrell, T. Green, A. Krupnick and E. Mansur. 1996. Tracking and Analysis Framework (TAF) Model Documentation

and User's Guide. An Interactive Model for Integrated Assessment of Title IV of the Clean Air Act Amendments. ANL/DIS/TM-36. Work sponsored by U.S. Department of Energy.

Sullivan, T.J. and D.F. Charles. 1995. The Role of Landscape Change in Surface Water Acidification. Report prepared for U.S. Department of Energy. DOE/ER/30196-6.

Sullivan, T.J. and B.J. Cosby. 1995. MAGIC Model Applications for Surface and Soil Waters as Input to the Tracking and Analysis Framework (TAF). Model Documentation. Report prepared for U.S. Department of Energy. DOE/ER/30196-7.

Eilers, J.M., C.L. Rose, and **T.J. Sullivan**. 1994. Status of air quality and effects of atmospheric pollutants on ecosystems in the Pacific Northwest Region of the National Park Service. Final Report submitted to the Air Quality Division, National Park Service, Denver, CO.

Sullivan, T.J., R.B. Raymond, J.A. Bernert, M. Gallagher, and J.M. Eilers. 1994. Watershed planning in Polk County. Final Report prepared for Polk County, City of Dallas, and Polk Soil and Water Conservation District.

Sullivan, T.J. and J.M. Eilers. 1994. Assessment of Deposition Levels of Sulfur and Nitrogen Required to Protect Aquatic Resources in Selected Sensitive Regions of North America. Final Report prepared for Technical Resources, Inc., Rockville, MD, Under Contract to U.S. Environmental Protection Agency, Environmental Research Laboratory-Corvallis, Corvallis, OR.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, H.F. Hemond, D.F. Charles, S.A. Norton, H.M. Seip, and G. Taugbøl. 1994. Confirmation of the MAGIC Model Using Independent Data: Influence of Organic Acids on Model Estimates of Lakewater Acidification. Report No. DOE/ER/30196-4. Final Report prepared for The U.S. Department of Energy, under Agreement No. DE-FG02-92ER30196.

Sullivan, T.J. and J.M. Eilers. 1992. Nitrogen effects studies in Europe. An evaluation of recent and on-going aquatic and terrestrial effects research projects. Report prepared for National Acid Precipitation Assessment Program. E&S Environmental Chemistry, Inc., Corvallis, OR.

Bernert, J.A., J.M. Eilers, K.J. Dueker, R. Vrana, R. Lycan, W.J. Ripple, and **T.J. Sullivan**. 1992. United States Fish and Wildlife Service, Region I. Geographic Information System Requirements Analysis/Strategic Plan. E&S Environmental Chemistry, Inc., Corvallis, OR

Sullivan, T.J., J. A. Bernert, E. A. Jenne, J. M. Eilers, B. J. Cosby, D. F. Charles, and A. R. Selle. 1991. Comparison of MAGIC and diatom paleolimnological model hindcasts of lakewater acidification in the Adirondack region of New York. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830. Pacific Northwest Laboratory, Richland, WA.

Eilers, J.M., F.A. Vertucci, and **T.J. Sullivan**. 1991. Lake chemistry in the Sawtooth Mountains, Idaho: monitoring issues in wilderness areas. Report #91-13, to the Sawtooth National Forest, Twin Falls, ID. E&S Environmental Chemistry, Inc., Corvallis, OR. 29 pp.

Sullivan, T.J., C.L. Rose, R.E. Gilfilian, J.M. Eilers, N. van Breemen, J.A. Bernert, D. Hanson, and B.E. Queitzsch. 1990. Nikiski Vegetation Impact Assessment. Executive Summary Report. Prepared for the Alaska Department of Environmental Conservation, Juneau, Alaska.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, E.A. Jenne, J.M. Eilers, D.F. Charles, and A.R. Selle. 1990. Comparison of paleolimnological and MAGIC model estimates of lakewater acidification in the Adirondack region. Acidic Deposition State of Science and Technology International Conference, Poster presentation, National Acid Precipitation Assessment Program; Hilton Head, South Carolina.

Bernert, J.A. and **T.J. Sullivan**. 1990. Historical Adirondack paleolimnological data base users guide. Report 90-02, E&S Environmental Chemistry, Inc., Corvallis, OR.

Pollman, C.D., D.A. Graetz, F.V. Ramsey, K.R. Reddy, and **T.J. Sullivan**. 1988. Feasibility of sediment removal and reuse for the restoration of Lake Apopka: Final Report for St. Johns River Water Management District. KBN Engineering and Applied Sciences, Inc., Gainesville, Florida.

Sullivan, T.J., H.M. Seip, and R.D. Vogt. 1987. Episodic changes in aluminum concentrations and other important parameters in stream and soil water in the Birkenes catchment, southernmost Norway. SI-Report 850701-2, Center for Industrial Research, Oslo.

Sullivan, T.J., N. Christophersen, and I.P. Muniz. 1987. Soil and streamwater chemistry during snowmelt at the Birkenes catchment, southernmost Norway, SI-Report 850701-1, Center for Industrial Research, Oslo.

Marmorek, D.R., D.P. Bernard, M.L. Jones, L.P. Rattie, and **T.J. Sullivan**. 1987. The Effects of Mineral Acid Deposition on Concentrations of Dissolved Organic Acids in Surface Waters. ESSA Environ. Social Syst. Anal., Ltd., Vancouver, B.C., Canada, 110 pp.

Presentations at National and International Conferences

McDonnell, T., M. Bell, C. Clark, J. Cosby, C. Driscoll, T. Greaver, B. Knees, J. Phelan, G.J. Reinds, **T. Sullivan**, A. Talhelm. Climate change and air pollution effects on soil and vegetation of the United States. Presentation for National Atmospheric Deposition Program (NADP) Fall 2022 Meeting, November 17, 2022.

McDonnell, T., C. Clark, G.J. Reinds, **T. Sullivan**, and B. Knees. 2021. Regional Critical Loads of Atmospheric Nitrogen Deposition for Terrestrial Vegetation: Case Study and Comparison. Presentation for National Atmospheric Deposition Program (NADP) Critical Loads of Atmospheric Deposition (CLAD) Virtual Seminar Series – Critical loads of N and S for herbaceous species and herbaceous richness. April 28, 2021.

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, **T. Sullivan**, and C. Clark. 2020. Vegetation Response Models and Regional Critical Loads of Atmospheric Nitrogen Deposition. National Atmospheric Deposition Program Fall Meeting and Scientific Symposium. October 29, 2020. Online meeting (originally scheduled for Knoxville, TN).

McDonnell, T.C., **T.J. Sullivan**, B. Knees, M. Bell, and E. Felker-Quinn. 2020. Intermodel Comparison of Atmospheric Nitrogen Deposition Estimates for the Conterminous United States and Critical Load Exceedance for Selected National Parks. National Atmospheric Deposition Program Total Deposition Science Committee (TDep), Spring 2020 Meeting. May 12, 2020. Online meeting (originally scheduled for Madison, WI).

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, **T. Sullivan**, and C. Clark. 2020. Biodiversity Modeling and Critical Loads Assessment in the USA. International Cooperative Programme on Modelling and Mapping of Critical Levels & Loads and Air Pollution Effects, Risks and Trends (ICP M&M) 36th Task Force Meeting, April 22, 2020. Online meeting (originally scheduled for Stockholm, Sweden).

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, M. Doviak, **T.J. Sullivan**, and C. Clark. 2020. Modeling habitat suitability for temperate forest understory vegetation. Presented at Adirondack Research Forum, Old Forge, NY, February 25, 2020.

Zarfos, M.R., M. Dovciak, G. Lawrence, T. McDonnell, and **T. Sullivan**. 2020. Understanding a 5-year shift in the composition of Adirondack hardwood seedling communities: the role of soil nutrients and climate. Presented at Adirondack Research Forum, Old Forge, NY, February 25, 2020.

McDonnell, T.C., **T.J. Sullivan**, C.T. Driscoll, B.J. Cosby, W.A. Jackson, G.B. Lawrence, D.A. Burns, C.A. Dolloff, C.M. Beier, P.F. Hessburg, N.A. Povak, and K.M. Reynolds. 2019. Regional Stream Acidification and Critical Loads in the Adirondack and Southern Appalachian Mountains Including Interactions with Climate Change. Presented at Society for Freshwater Science Annual Meeting, Salt Lake City, Utah, May 22, 2019.

Driscoll, C.T., S. Shao, **T.J. Sullivan, T.**C. McDonnell, B.P. Baldigo, D.A. Burns, and G.B. Lawrence. 2018. Responses of Streams in the Adirondack Mountains to Changes in Atmospheric Deposition of Sulfur and Nitrogen: Past and Future Acidification and Target Loads of Deposition to Promote Resource Recovery. Presented at the Adirondack Acid Rain Conference in Saratoga Springs, NY. November 29, 2018.

McDonnell, T., C. Clark, M. Bell, and **T. Sullivan**. 2018. Habitat Suitability for Understory Vegetation – Critical Loads Development and Assessment. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Albany, NY, November 6, 2018.

Burns, D., G. Lawrence., **T. Sullivan**, C. Driscoll, S. Shao and T. McDonnell. 2017. Episodic Acidification in the Adirondack Region of New York: Spatial Patterns and Evidence of Recovery. NADP Fall Meeting, San Diego, CA, October 30-November 3, 2017.

Zarfos, M.R., M. Dovciak, G.B. Lawrence, T.C. McDonnell, and **T.J. Sullivan**. 2017. Effects of Acidic Deposition and a Soil Acidification Gradient on Forest Understory Plant Richness And Composition in the Adirondack Mountains, New York. Ecological Society of American Annual Meeting, Portland, OR, August 6-11, 2017.

Lapenis, A., A. Buyantuev, S. Jiang, G. Lawrence, **T. Sullivan, T.** McDonnell, and S. Bailey. 2016. Spring Phenology – A Newly Identified Ecophysiological Role of the Deciduous Forest Floor. American Geophysical Union Fall Meeting, San Francisco, CA, December 12-16, 2016.

Lawrence, G.B., **T.J. Sullivan, T.**C. McDonnell, S.W. Bailey, M. Dovciak and M.R. Antidormi. 2016. Influence of Soil-Base Availability on Composition and Structure of Adirondack,

NY, Sugar Maple-Beech Forests. Soil Science Society of America Annual Meeting, Phoenix, AZ, November 6-9, 2016.

Sullivan, T., McDonnell, T., Beier, C, Belyazid, S., Burns, D., Clark, C. , Cosby, B., Dovciak, M., Driscoll, C., Jackson, W., Lawrence, G., Reinds, G., Sams, C., Shao, S., and Whalen, M. 2016. Ecosystem Recovery from S and N Deposition and Associated Critical Loads in Context of Changing Climate. NADP Fall Meeting, Santa Fe, NM, November, 2016.

Barna, M., T. Moore, **T. Sullivan, T.** McDonnell, and T. Thompson. 2016. Simulating the Contribution of Emissions from Oil and Gas Development to Regional Nitrogen Deposition at National Parks in the Intermountain West. International Global Atmospheric Chemistry, Breckenridge, CO, September 26-30, 2016.

McDonnell, T., S. Belyazid, L. Bonten, C. Clark, G.J. Reinds, and **T. Sullivan**. 2016. Exploring Coupled Dynamic Biogeochemical and Vegetation Models in Temperate Forest Ecosystems of the Eastern United States. 26th CCE Workshop and 32nd ICP M&M Task Force Meeting, Dessau, Germany, April 19-22, 2016.

Lawrence, G.B., D.S. Ross, **T.J. Sullivan, T.**C. McDonnell, S.W. Bailey, and J.E. Dukett. 2015. Combining Long-Term Watershed Monitoring at Buck Creek with Spatially Extensive Ecosystem Data to Understand the Processes of Acid Rain Effects and Recovery. American Geophysical Union Fall meeting. San Francisco, CA, December 14-18, 2015.

McDonnell, T.C. and **Sullivan, T.J.** 2014. Evaluating Effects of Atmospheric N and S Deposition and Climate on Forest Ecosystem Services Based on the Critical Loads Paradigm. International Union of Forest Research Organizations. XXIV World Congress, Salt Lake City, UT, October 5-11, 2014.

Sullivan, T.J., T.C. McDonnell, K. Reynolds, P. Hessburg, N. Povak, and B. Salter. 2013. Ecosystem Management Decision Support (EMDS). Surface Water Acidification in the Southern Appalachian Mountains. ESE/EMDS Workshop. U.S. Forest Service Region 8 Air Resource Management, Asheville, NC, April 9th, 2013.

Sullivan, T.J. and T.C. McDonnell. 2012. Critical Loads Approach to Ecosystem Services. Presented at 2012 NADP Annual Meeting and Scientific Symposium: The NADP Cooperative: State, Local and Tribal Perspectives, Portland, ME, October 2-5, 2012.

Sullivan, T., T.C. McDonnell, B. Cosby, C. Driscoll, G. Lawrence, S. Bailey, H. Sverdrup, S. Belyazid, P. Hessburg, N. Povak, and K. Reynolds. 2012. Modeling Critical Loads Using Process Models: Recent Efforts. Presented at NADP Conference, Portland, OR, April 2012.

Reynolds, K., P. Hessburg, **T. Sullivan**, N. Povak, T.C. McDonnell, B. Cosby, and W. Jackson. 2012. Spatial Decision Support for Assessing Impacts of Atmospheric Sulfur Deposition on Aquatic Ecosystems in the Southern Appalachian Region. Proceedings of the 45th Hawaiian International Conference on System Sciences. 4-7 January 2012, Maui, Hawaii. 10 pp.

McDonnell, T.C., **T.J. Sullivan**, K. Reynolds, P. Hessburg, N. Povak, and B. Salter. 2011. Biological Response & Sulfur Critical Loads. Presented at EMDS Workshop at NADP Meeting, Pensacola, FL, May 5, 2011.

Sullivan, T.J., T. C. McDonnell, G. T. McPherson, E. Porter, S. D. Mackey, and D. Moore. 2011. Use of GIS to Evaluate Sensitivity of I&M Parks to Effects from Atmospheric Nitrogen Deposition. Presented at The George Wright Society Conference on Parks, Protected Areas, & Cultural Sites, New Orleans, LA, March 14-18, 2011.

Sullivan, T.J., Cosby, B.J., McDonnell, T.C., and Driscoll, C.T. 2011. Modeling Critical Loads, New York and Beyond. Presented at New York State Research and Development Authority (NYSERDA) Conference, Environmental Monitoring, Evaluation, and Protection in New York: Linking Science and Policy. Albany, NY, November 15-16, 2011.

Sullivan, T.J., B.J. Cosby, and T.C. McDonnell. 2010. Steady State Aquatic Critical Loads for Acid Sensitive Portions of Virginia and West Virginia. Final Results of SE Multiagency Critical Load Project. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Memphis, TN, April 20-21, 2010.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, T.C. McDonnell, Q. Zhou, and D. Burns. 2010. Development of Critical Loads for the Protection of Acid-Sensitive Resources in the Adirondack Mountains, New York. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Memphis, TN, April 20-21, 2010.

Sullivan, T.J., B.J. Cosby, T.C. McDonnell, C.T. Driscoll, A.T. Herlihy, and D.A. Burns. 2010. MAGIC Model Estimates of Critical Load of Sulfur Deposition to Protect Acid-Sensitive Resources in the Adirondack Mountains, New York. Presented at 2010 National Atmospheric Deposition Program Annual Meeting & Scientific Symposium, Networking the Networks, Lake Tahoe, CA, October 19-21, 2010.

Hessburg, P., K. Reynolds, **T. Sullivan**, B. Jackson, M. Povak, B. Salter, and T. McDonnell. 2010. Progress on Implementation of a Decision-Support System to Assess Critical Loads of Atmospheric S Deposition in the Southeastern US. Presented at 2010 National Atmospheric Deposition Program Annual Meeting & Scientific Symposium, Networking the Networks, Lake Tahoe, CA, October 19-21, 2010.

Sverdrup, H., **T. Sullivan**, B. Nihlgård, S. Belyazid, T. McDonnell, and B. Rihm. 2010. Testing the Feasibility of Using ForSAFE---VEG for Mapping Critical Loads for Nitrogen Based on Biodiversity in the Rocky Mountains Region. Presented at Critical Loads Ad Hoc (CLAD) Committee Meeting, Lake Tahoe, CA, October 19-21, 2010.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, T.C. McDonnell, Q. Zhou, and D.A. Burns. 2009. Use of Critical Deposition Loads to Inform Environmental Protection Strategies. Presented at NYSERDA Conference. Environmental Monitoring, Evaluation, and Protection: Linking Science and Policy, Albany, NY, October 14-15, 2009.

Sullivan, T.J., B.J. Cosby, and T.C. McDonnell. 2009. Critical Loads for Protection of Aquatic Resources in the Blue Ridge, Ridge and Valley, and Appalachian Plateau Ecoregions of Virginia and West Virginia. Presented at 2009 Annual Meeting and Scientific Symposium. National Atmospheric Deposition Program, Saratoga Springs, NY, October 6-9, 2009.

Sullivan, T., B. Cosby, and T.C. McDonnell. 2009. Aquatic Critical Loads in Virginia and West Virginia. Research Results. Presented at Critical Loads Ad Hoc (CLAD) Meeting, Pensacola, FL, April 2009.

Sullivan, T., C. Driscoll, B. Cosby, D. Burns, A. Herlihy, and T.C. McDonnell. 2009. Critical Loads to Adirondack Lake Watersheds. Progress Report. Presented at Critical Loads Ad Hoc (CLAD) Meeting, Pensacola, FL, April 2009.

Sullivan, T., T. McDonnell, and B. Cosby. 2008. Progress on the Multi-Agency Critical Loads Project. NADP Meeting, Madison WI. October, 2008.

McNulty, S., E. Cohen, H. Li, J. Moore Myers, and **T. Sullivan**. 2008. Estimates of critical acid loads and exceedances for forest soils across the conterminous United States. Paper presented at the 23rd International Union of Forest Research Organizations (IUFRO) Conference, Air Pollution and Climate Change at Contrasting Altitude and Latitude, September 7-12, 2008, Murten, Switzerland.

Sullivan, T.J. and B.J. Cosby. 2006. MAGIC model calculations of critical loads of acidic deposition for the protection of U.S. surface waters. Multi-Agency Critical Loads Workshop on Sulfur and Nitrogen Deposition Effects on Freshwater and Terrestrial Ecosystems, Charlottesville, VA, May 23-24, 2006.

Sullivan, T.J., B.J. Cosby, and C.T. Driscoll. Calculation of critical loads of acidic deposition for the protection of acid-sensitive surface waters. Paper presented at NADP 2006: Effects of Deposition in Coastal and Urban Environments, October 24-26, 2006, Norfolk, VA.

Herlihy, A., R. Hughes, and **T. Sullivan**. 2006. Developing reference conditions, indicators, field methodology, and indices of biotic integrity for a national lakes survey. Planning a Survey of the Nation's Lakes. National conference co-sponsored by U.S. Environmental Protection Agency, Chicago Botanic Garden, and North American Lake Management Society. Chicago, IL. April 25-28, 2006.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2006. Relationship between size of vegetated buffers and transport of fecal coliform bacteria from pasturelands treated with dairy cow manure. Paper presented at American Dairy Science Association/American Society of Animal Science Association Joint Meeting, July 9-13, 2006, Minneapolis, MN.

Sullivan, T., C. Boyle, B.J. Cosby, C. Driscoll, I. Fernandez, A. Herlihy, T. McDonnell, E. Miller, S. Nierzwicki-Bauer, N. Nowicki, K. Snyder, R. Stemberger, and J. Sutherland. 2003. Assessment of extent to which intensively-studied lakes are representative of the Adirondack Mountain region, New York. Poster Presentation, American Geophysical Union, San Francisco, 8-12 December, 2003.

Sullivan, T.J., J.A. Bernert, M. Wustenberg, and J. Moore. Assessment of Water Quality in the Five Major Rivers that Flow into Tillamook Bay. 20th Annual Meeting, Pacific Estuarine Research Society, Tillamook, OR, May 15-17, 1997.

Sullivan, T.J. and B.J. Cosby. Testing, Improvement, and Confirmation of a Watershed Model of Acid-Base Chemistry. 5th Intern. Conf. on Acidic Deposition, Gothenberg, Sweden, 26-30 June, 1995.

Sullivan, T.J. and J.M. Eilers. Ecological effects of sulfur and nitrogen deposition in the Pacific Northwest Region. Meeting of the International Joint Commission, Vancouver, BC, Canada, October, 1995 (Invited).

Sullivan, T.J. Acid Rain as a Threat to Aquatic Resources. Sustainable Society and Protected Areas. 8th Conference on Research and Resource Management in Parks and on Public Lands, Portland, OR, April 17-21, 1995.

Sullivan, T.J., B.J. Cosby, S.A. Norton, D.F. Charles, R.F. Wright, and E. Gjessing. Multisite testing and evaluation of a geochemical model of acid-base chemistry: Confirmation of the MAGIC model using catchment manipulation experiments and historical diatom inferences. Poster presentation, Third International Symposium on Ecosystem Manipulation, Windermere, England, October 1994.

Sullivan, T.J. Evaluation of biogeochemical models using data from experimental ecosystem manipulations. Third International Symposium on Ecosystem Manipulation, Windermere, England, October, 1994 (Invited).

Sullivan, T.J. Progress in quantifying the role of aluminum in acidification of surface and soil waters. Intern. Conf. on Aluminum in the Environment, Lublin, Poland, 19-22 September, 1994 (Invited).

Sullivan, T.J., R.S. Turner, D.F. Charles, B.F. Cumming, J.P. Smol, C.L. Schofield, C.T. Driscoll, B.J. Cosby, H.J.B. Birks, A.J. Uutala, J.C. Kingston, S.S. Dixit, J.A. Bernert, P.F. Ryan, and D.R. Marmorek. 1992. Use of historical assessment for evaluation of process-based model projections of future environmental change: Lake acidification in the Adirondack Mountains, New York, U.S.A. 4th Intern. Conf. on Acidic Deposition, Glasgow, Scotland, 1990.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, E.A. Jenne, J.M. Eilers, D.F. Charles, and A.R. Selle. 1990. Comparison of paleolimnological and MAGIC model estimates of lakewater acidification in the Adirondack region. Acidic Deposition State of Science and Technology International Conference, Poster presentation, National Acid Precipitation Assessment Program; Hilton Head, South Carolina.

Sullivan, T.J. 1990. Historical changes in the acid-base chemistry of lakes and streams throughout the United States. Acidic Deposition, State of Science and Technology International Conference, Hilton Head, South Carolina (Invited).

Sullivan, T.J. Aqueous aluminum speciation in acidified areas of southernmost Norway. Presented at Norwegian Chemical Society, Annual Meeting, Oslo. April, 1986.

Attachment B – CV of Todd C. McDonnell

Todd C. McDonnell, Ph.D.
President and Principal Scientist
E&S Environmental Chemistry, Inc.
Corvallis, OR

Education

Ph.D. 2014 **Oregon State University**
College of Forestry: Forest Ecosystems and Society

M.P.S. 2003 **State University of New York**
College of Environmental Science and Forestry: Forest Hydrology and Watershed Management

B.A. 2001 **The George Washington University**
School of Engineering and Applied Science: Applied Science and Technology – Environmental Science

Relevant Experience

Dr. McDonnell is an environmental scientist with 25 years of experience in water quality assessment, environmental modeling, harmful algal blooms, and agricultural best management practices. He has extensive experience with risk assessment to inform decision making related to anthropogenic impacts on a wide range of environmental components including water and soil chemistry, fisheries, and vegetation. Dr. McDonnell has developed watershed assessments to evaluate physiochemical and biological conditions including aspects of hydrology, water quality, soils, fisheries, wildlife, vegetation, and land use throughout the United States. Dr. McDonnell is experienced with implementation and monitoring related to agricultural best management practices for nutrient pollution reduction while working with E&S and during prior experience with the Ontario County, New York Soil and Water Conservation District and Canandaigua Lake Watershed Council. He regularly communicates project results to project stakeholders through peer-reviewed journal articles, agency reports, and oral presentations. Dr. McDonnell is an advisory board member of the U.S. Critical Loads of Atmospheric Deposition Science Committee of the National Atmospheric Deposition Program. He has served as the principal investigator and/or technical lead on a wide variety of collaborative environmental research and restoration projects conducted by E&S. Most have focused on environmental pollution and its effects on aquatic and terrestrial systems. Some examples are highlighted below.

Selected Projects

Water Quality Assessment of the Klamath River Basin

- Research, monitoring, and assessment of riverine water quality and reservoir harmful algal bloom conditions in the Klamath River Basin; E&S efforts have been ongoing for more than 20 years.
- Lead project manager

Klamath River Watershed Chinook Population Dynamics

- Conduct water quality and statistical modeling to develop environmental co-variates for understanding drivers of historical Chinook salmon populations in the Lower Klamath River Watershed.
- Co-author of peer-reviewed manuscript in preparation

Habitat Suitability Modeling for Acid- and Thermally-Sensitive Stream Biota in the Southern Appalachian Mountains

- Developed statistical models to estimate the sensitivity of stream water temperature to forecasted increases in air temperature.
- Lead author of journal article

Tillamook Bay Watershed Research

- Implemented efforts related water quality monitoring to evaluate effectiveness of riparian buffers for reducing concentrations and loads of nutrients, sediment, and fecal coliform bacteria in the Tillamook Bay Watershed.

Canandaigua Lake Watershed Monitoring and Assessment

- Implemented watershed monitoring and restoration activities including streambank stabilization, agricultural best management practices, and water quality characterization.

Oregon Watershed Assessments

- Implemented watershed assessment analyses following both state and federal guidelines to evaluate aspects of water quality, hydrology, water use, fisheries, and aquatic habitat in mixed land use watersheds of Oregon.
- Co-author of multiple reports

Ecosystem Risk Assessment of U.S. National Parks

- Developed a risk assessment model to rank all U.S. National Parks based on sensitivity to nutrient enrichment and acidic deposition.
- Co-author of agency report

Spatial Statistical Modeling for Predicting Stream Water Acid Neutralizing Capacity in George Washington National Forest, Virginia

- Development and application of a novel spatial stream network analysis approach to evaluate stream water acidity for all streams located on the George Washington National Forest.
- Lead author of agency report

Appalachian Trail Atmospheric Deposition Effects Study

- Conducted the development of dynamic critical loads of atmospheric nitrogen and sulfur deposition to protect aquatic and terrestrial biota and extrapolated process-model results throughout a 20-km corridor along the entire Appalachian Trail from Maine to Georgia.
- Co-authored journal article and agency report

Climate and Atmospheric Deposition Terrestrial Vegetation Effects Modeling

- Conducted statistical model development to evaluate effects of changing climate and atmospheric nitrogen and sulfur deposition on vegetation communities across the United States.
- Lead author of journal article

Critical Loads of Atmospheric Nitrogen and Sulfur Deposition in the Intermountain Region of the US Forest Service

- Data analysis and assessment of the expected risk to various biological endpoints (e.g., surface waters, trees, lichen) from air pollution within all 12 National Forests and 50 wilderness areas of the USFS Intermountain Region (R4).
- Lead author of agency report

Modeling Tree Species Response to Climate Change, Air Pollution, and Forest Disturbance

- Working in collaboration with researchers at EPA, USFS, and USGS; a primary objective of this project was to generate climate and air pollution thresholds to be used for decision making related to forest management and environmental policy on federal lands.
- Lead author of journal article in preparation

Greenhouse Gas Budget for New York State's Natural and Working Lands

- Conducted the development and reporting of net greenhouse gas emissions associated with forest, agricultural, and wetland systems of New York State (NYSERDA) in contribution towards a decarbonization project across all emission sectors of New York State.
- Lead author of agency report

Willamette River Basin Chinook Salmon Database Design for Oregon Department of Fish and Wildlife

- Designed a relational database to include data on salmonid distribution and abundance and associated attributes for nearly 50 drainages located throughout the Willamette River Basin in Oregon
- Lead developer

Garcia River and Tuolumne River Stream Temperature Modeling

- Developed estimates of stream surface solar radiation exposure for temperature modeling to support salmonid conservation research in California streams
- Lead developer

Reference Lake Selection for EPA's National Lake Survey

- Conducted GIS data analyses to determine lake watershed disturbance rankings to assess lake watershed conditions throughout several regions of the United States.
- Co-author of journal article

Devils Lake Water Quality Database Design

- Developed a relational database containing physical, chemical, and biological measurements from water quality monitoring of Devils Lake, Oregon.
- Lead developer

Operational, seasonal, and decadal forecasts of harmful algal blooms (HABs) in Lake Okeechobee

- Predictive analytics to develop short and long-term forecasts of HABs for Lake Okeechobee.

Bathymetric Map Development of River Forest Lake

- Collected field data and created digital maps displaying the bathymetry for an urban lake

Computer Applications

Geographic information systems: ArcGIS 3.x – 10.x, Pro; QGIS
Computer programming: Python, R
Environmental modeling: Steady State Water Chemistry (SSWC), Simple Mass Balance (SMB), VSD+PROPS

Professional Memberships

Critical Loads of Atmospheric Deposition (CLAD) Science Advisory Board Member
Centre for Dynamic Modelling (CDM)
American Geophysical Union
Ecological Society of America
Society for Conservation GIS

Published Journal Articles

Tourville, J.C., M.R. Zarfos, G.B. Lawrence, **T.C. McDonnell**, T.J. Sullivan, and M. Dovčiak. 2023. Soil biotic and abiotic thresholds in sugar maple and American beech seedling establishment in forests of the northeastern United States. Plant Soil. 10.1007/s11104-023-06123-2.

McDonnell, T.C., J. Phelan, A.F. Talhelm, B.J. Cosby, C.T. Driscoll, T.J. Sullivan, and T. Greaver. 2023. Protection of forest ecosystems in the eastern United States from elevated atmospheric deposition of sulfur and nitrogen: A comparison of steady-state and dynamic model results. Environ. Pollut. 10.1016/j.envpol.2022.120887.

McDonnell, T.C., C.M. Clark, G.J. Reinds, T.J. Sullivan, and B. Knees. 2022. Modeled vegetation community trajectories: Effects from climate change, atmospheric nitrogen deposition, and soil acidification recovery. Environmental Advances 9:100271. 10.1016/j.envadv.2022.100271.

McDonnell, T.C., C.T. Driscoll, T.J. Sullivan, D.A. Burns, B.P. Baldigo, S. Shao, and G.B. Lawrence. 2021. Regional target loads of atmospheric nitrogen and sulfur deposition for the protection of stream and watershed soil resources of the Adirondack Mountains, USA. Environ. Pollut. 281:117110. 10.1016/j.envpol.2021.117110.

McDonnell, T.C., G.J. Reinds, G.W.W. Wamelink, P.W. Goedhart, M. Posch, T.J. Sullivan, and C.M. Clark. 2020. Threshold Effects of Air Pollution and Climate Change on Understory Plant Communities at Forested Sites in the Eastern United States. Environ. Pollut. 262. 10.1016/j.envpol.2020.114351.

Shao, S., C.T. Driscoll, T.J. Sullivan, D.A. Burns, B.P. Baldigo, G.B. Lawrence, and **T.C. McDonnell**. 2020. The response of stream ecosystems in the Adirondack region of New York to historical and future changes in atmospheric deposition of sulfur and nitrogen. Sci. Total Environ. doi:org/10.1016/j.scitotenv.2020.137113.

Burns, D.A., **T.C. McDonnell**, K.C. Rice, G.B. Lawrence, and T.J. Sullivan. 2020. Chronic and episodic acidification of streams along the Appalachian Trail corridor, eastern United States. Hydrol. Process. 10.1002/hyp.13668 34:1498-1513.

Zarfos, M.R., M. Dovciak, G.B. Lawrence, **T.C. McDonnell**, and T.J. Sullivan. 2019. Plant richness and composition in hardwood forest understories vary along an acidic deposition and soil-chemical gradient in the northeastern United States. Plant Soil. 10.1007/s11104-019-04031-y

McDonnell, T.C., S. Belyazid, T.J. Sullivan, M. Bell, C. Clark, T. Blett, T. Evans, W. Cass, A. Hyduke, and H. Sverdrup. 2018. Vegetation dynamics associated with changes in atmospheric nitrogen deposition and climate in hardwood forests of Shenandoah and Great Smoky Mountains national parks, USA. Environ. Pollut. 237:662-674. 10.1016/j.envpol.2018.01.112.

McDonnell, T.C., G.J. Reinds, T.J. Sullivan, C.M. Clark, L.T.C. Bonten, J.P. Mol-Dijkstra, G.W.W. Wamelink, and M. Dovciak. 2018. Feasibility of coupled empirical and dynamic modeling to assess climate change and air pollution impacts on temperate forest vegetation of the eastern United States. Environ. Pollut. 234:902-914. doi.org/10.1016/j.envpol.2017.12.002.

McDonnell, T.C., T.J. Sullivan, and C.M. Beier. 2018. Influence of climate on long-term recovery of Adirondack Mountain lakewater chemistry from atmospheric deposition of sulfur and nitrogen. Adir. J. Environ. Stud. 22:20-45.

Lawrence, G.B., **T.C. McDonnell**, T.J. Sullivan, M. Dovciak, S.W. Bailey, M.R. Antidormi, and M.R. Zarfos. 2017. Soil base saturation combines with beech bark disease to influence composition and structure of sugar maple-beech forests in an acid rain-impacted region. Ecosystems 10.1007/s10021-017-0186-0.

McDonnell, T.C., M.R. Sloat, T.J. Sullivan, C.A. Dolloff, P.F. Hessburg, N.A. Povak, W.A Jackson, and C. Sams. 2015. Downstream warming and headwater acidity may diminish coldwater habitat in southern Appalachian Mountain streams. Plos One. DOI:10.1371/journal.pone.0134757.

McDonnell, T.C., T.J. Sullivan, P.F. Hessburg, K.M. Reynolds, N.A. Povak, B.J. Cosby, W. Jackson, and R.B. Salter. 2014. Steady-state sulfur critical loads and exceedances for protection of aquatic ecosystems in the US southern Appalachian Mountains. J. Environ. Manage. 146:407-419.

McDonnell, T.C., S. Belyazid, T.J. Sullivan, H. Sverdrup, W.D. Bowman, and E.M. Porter. 2014. Modeled subalpine plant community response to climate change and atmospheric nitrogen deposition in Rocky Mountain National Park, USA. Environ. Pollut. 187:55-64.

Povak, N.A., P.F. Hessburg, **T.C. McDonnell**, K.M. Reynolds, T.J. Sullivan, R.B. Salter, and B.J. Cosby. 2014. Machine learning and linear regression models to predict catchment-level base cation weathering rates across the southern Appalachian Mountain region, USA. Water Resour. Res. DOI: 10.1002/2013WR014203.

McDonnell, T.C., T.J. Sullivan, B.J. Cosby, W.A. Jackson, and K. Elliott. 2013. Effects of climate, land management, and sulfur deposition on soil base cation supply in national forests of the Southern Appalachian Mountains. Water Air Soil Pollut. 224:1733. DOI 10.1007/s11270-013-1733-8.

Sullivan, T.J., G.B. Lawrence, S.W. Bailey, **T.C. McDonnell**, C.M. Beier, K.C. Weathers, G.T. McPherson, and D.A. Bishop. 2013. Effects of acidic deposition and soil acidification on sugar maple in the Adirondack Mountains, New York. Environ. Sci. Technol. 47:12687-12694. 10.1021/es401864w.

Povak, N.A, Hessburg, P.F., Reynolds, K.M., Sullivan, T.J., **McDonnell, T.C.**, and Salter, R.B. 2013. Machine learning and hurdle models improve regional predictions of stream water acid neutralizing capacity. Water Resour. Res. doi: 10.1002/wrcr.20308.

Herlihy, A.T., J.B. Sobota, **T.C. McDonnell**, T.J. Sullivan, S. Lehmann, and E. Tarquinio. 2013. An a priori process for selecting candidate reference lakes for a national survey. Freshw. Sci. 32(2):385-396.

McDonnell, T.C., B.J. Cosby, and T.J. Sullivan. 2012. Regionalization of soil base cation weathering for evaluating stream water acidification in the Appalachian Mountains, USA. Environmental Pollution 162:338-344

Sullivan, T.J., B.J. Cosby, **T.C. McDonnell**, E. Porter, T. Blett, R. Haeuber, C.M. Huber, and J. Lynch. 2012. Critical loads of acidity to protect and restore acid-sensitive streams in Virginia and West Virginia. Water Air and Soil Pollution. 223:5759–5771. doi: 10.1007/s11270-012-1312-4.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, **T.C. McDonnell**, A.T. Herlihy, and D.A. Burns. 2012. Target loads of atmospheric sulfur and nitrogen deposition for protection of acid sensitive aquatic resources in the Adirondack Mountains, New York. Water Resources Research. 48: WO 1547, doi:10.1029/2011WR011171

Sverdrup, H., **T.C. McDonnell**, T.J. Sullivan, B. Nihlgård, S. Belyazid, B. Rihm, E. Porter, W.D. Bowman, and L. Geiser. 2011. Testing the feasibility of using the ForSAFE-VEG model to map the critical load of nitrogen to protect plant biodiversity in the Rocky Mountains region, USA. Water Air Soil Pollut. DOI 10.1007/s11270-011-0865-y.

McDonnell, T.C., B.J. Cosby, T.J. Sullivan, S.G. McNulty, E.C. Cohen. 2010. Comparison among model estimates of critical loads of acidic deposition using different sources and scales of input data. Environ. Pollut. 158:2934-2939.

McNeil, B.E., J.M. Read, T.J. Sullivan, **T.C. McDonnell**, I.J. Fernandez, and C.T. Driscoll. 2008. The spatial pattern of nitrogen cycling in the Adirondack Park, New York. Ecol. Appl. 18(2):438-452.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, C.T. Driscoll, I.J. Fernandez, **T. C. McDonnell**, K.U. Snyder. 2007. Assessment of the extent to which intensively-studied lakes are representative of the Adirondack region and response to future changes in acidic deposition. Water Air Soil Pollut. 185:279-291.

Sullivan, T.J., I.J. Fernandez, A.T. Herlihy, **T.C. McDonnell**, N.A. Nowicki, K.U. Snyder, and J.W. Sutherland. 2006. Acid-base characteristics of soils in the Adirondack Mountains, New York. Soil Sci. Soc. Amer. J. 70: 141-152.

Published Reports

McDonnell, T.C., B. Knees, M.D. Bell, and E. Felker-Quinn. 2024. Effects of climate change and atmospheric nitrogen deposition on forest understory vegetation communities in selected U. S. national parks. National Park Service, Fort Collins, CO. 1 - 26 pp.

McDonnell, T.C., S. Harju, and C.M. Clark. 2024. Tree Growth and Survival Response to Air Pollution, Climate, and Biogeographic Conditions: Initial Bayesian Model Development. White Paper. Prepared for U.S. Environmental Protection Agency. 33 pp.

McDonnell, T.C., P. Gruendike, M. Deas, and D. Ebert. 2023. Evaluation of Thermal Refugia and Habitat Restoration Opportunities of the Klamath River between J.C. Boyle Dam and Copco Reservoir. Prepared for PacifiCorp. 101 pp.

McDonnell, T., M. Diabat, and C. Miwa. 2022. Upper Klamath River - Thermal Infrared Airborne Imagery - Technical Data Report. Prepared for PacifiCorp. 38 pp. July 21. Available online: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/hydro/klamath-river/khsa-implementation/technical-documents/2022-01-14_Thermal-Imaging-Tech-Data-Rpt-KL.pdf.

McMurray, J.A., **T.C. McDonnell**, A.E. Mebane, L.H. Pardo. 2021. Assessment of atmospheric nitrogen and sulfur deposition critical loads for aquatic and terrestrial resources on National Forest System lands in the Intermountain Region. Gen. Tech. Rep. NRS-204. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 308 p. https://doi.org/10.2737/NRS-GTR-204.

Lynch, J.A., J. Phelan, L.H. Pardo, **T.C. McDonnell**, C.M. Clark, and M.D. Bell. 2020. Detailed Documentation of the National Critical Load Database (NCLD) for U.S. Critical Loads of Sulfur and Nitrogen, version 3.1, National Atmospheric Deposition Program, Wisconsin State Laboratory of Hygiene, Madison, WI.

Chione, A, **T. McDonnell**, N. Rudh, and T. Spoerer, R. Flitcroft, J. Armstrong, B. Hansen, and M. Sloat. 2020. Field Investigation to Support Coho Salmon Research in the Tahkenitch Lake Watershed. Report Prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

Driscoll, C.T., T.J. Sullivan, B.P. Baldigo, D.A. Burns. S. Shao. **T.C. McDonnell**, and G.B. Lawrence. 2020. Responses of Streams in the Adirondack Mountains to Changes in Atmospheric Deposition of Sulfur and Nitrogen: Past and Future Acidification and Target Loads of Deposition to Promote Resource Recovery. Report Number 20-19. New York State Energy Research and Development Authority, Albany, NY.

McDonnell, T.C., T.J. Sullivan, P.B. Woodbury, J.L. Wightman, G.M. Domke, C.M. Beier, and C. Trettin. 2020. Sources and Sinks of Major Greenhouse Gases Associated with New York State's Natural and Working Lands: Forests, Farms, and Wetlands. Report Number 20-06. New York State Energy Research and Development Authority, Albany, NY.

McDonnell, T.C., T.J. Sullivan, B. Knees, M. Bell, and E. Felker-Quinn. 2020. Intermodel Comparison of Atmospheric Nitrogen Deposition Estimates for the Conterminous United States and Critical Load Exceedance for Selected National Parks. Natural Resource Report NPS/NRSS/ARD/NRR—2020/2125. National Park Service, Fort Collins, Colorado.

Lawrence, G.B., M.R. Antidormi, **T.C. McDonnell**, T.J. Sullivan, and S.W. Bailey. 2020. Adirondack New York soil chemistry data, 1992-2017. U.S. Geological Survey data release, https://doi.org/10.5066/P9YAWR0N.

McDonnell, T.C., T.J. Sullivan, and D.L. Moore. 2019. Critical Loads of Atmospheric Nitrogen and Sulfur Deposition for Protection of Sensitive Aquatic and Terrestrial Resources in the Intermountain Region of the USDA Forest Service. Report Prepared for the USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C., J. Aherne, T.J. Sullivan, C. Barton, C. Cotton, and B. Jackson. 2019. Variation in Forest Soil-Nutrient Availability: Dynamic Model Estimates of Past and Future Conditions at Two Sites in the Daniel Boone National Forest, Kentucky, USA. Report Prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

Lynch, J.A., J. Phelan, L. Pardo, **T. McDonnell**, and C.M. Clark. 2019. Detailed Documentation of the National Critical Load Database (NCLD) for U.S. Critical Loads of Sulfur and Nitrogen, Version 3.1. National Atmospheric Deposition Program, Madison, WI.

McDonnell, T.C., T.J. Sullivan, J. Farmer, J. Rash, and W.A. Jackson. 2018. Effectiveness of Experimental Stream Liming in the Upper Santeetlah Watershed of Western North Carolina. Report Prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C., W.A. Jackson, B.J. Cosby, and T.J. Sullivan. 2018. Atmospheric Deposition Effects Modeling for Resource Management on Southern Appalachian National Forests. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., M.R. Zarfos, M. Dovciak, **T.C. McDonnell**, and G.B. Lawrence. 2018. Effects of Acid Deposition on the Biodiversity of Forest Understory Plant Communities in the Northern Hardwood Forests of the Adirondack Mountain Region. Final Technical Report 18-17. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

McDonnell, T.C., T.J. Sullivan, B.J. Cosby, W.A Jackson, and D.L. Moore. 2017. Estimating the Amount of Sulfur Deposition the Sipsey and Cohutta Wilderness Areas Can Tolerate While Protecting the Acid Neutralizing Capacity of Perennial Streams. Report prepared for USDA Forest Service. E&S Environmental Chemistry, Inc., Corvallis, OR.

Lynch, J.A., J. Phelan, L.H. Pardo, **T.C. McDonnell**, and C.M. Clark. 2017. Detailed Documentation of the National Critical Load Database (NCLD) for U.S. Critical Loads of Sulfur and Nitrogen, version 3.0. National Atmospheric Deposition Program, Illinois State Water Survey, Champaign, IL.

Lawrence, G.B., T.J. Sullivan, **T.C. McDonnell**, M. Dovciak, S.W. Bailey, M.R. Antidormi, and M.R. Zarfos. 2017 Soil Acidification and Beech Bark Disease: Influencing the Composition and Structure of Sugar Maple/Beech Forests. Summary Report 17-26 prepared for the New York State Energy Research and Development Authority. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., **T.C. McDonnell**, G.B. Lawrence, M. Dovciak, and M.R. Zarfos. 2017. Acidification and Forest Understory Plant Communities in the Adirondack Mountains. Summary Report. 17-27. New York State Energy Research and Development Authority, Albany, NY.

Sullivan, T.J., **T.C. McDonnell**, D.L. Moore, and M.G. Barna. 2016. Mapping of Nitrogen Critical Loads for Selected National Parks in the Western United States. Natural Resource Report NPS/NRSS/ARD/NRR—2016/1286. National Park Service, Fort Collins, Colorado.

Lawrence, G.B., T.J. Sullivan, D.A. Burns, S.W. Bailey, B. J. Cosby, M. Dovciak, H.A. Ewing, **T.C. McDonnell**, R. Minocha, R. Riemann, J. Quant , K.C. Rice, J. Siemion, K. Weathers. 2015. Acidic Deposition along the Appalachian Trail Corridor and its Effects on Acid-Sensitive Terrestrial and Aquatic Resources. Results of the Appalachian Trail MEGA-Transect Atmospheric Deposition Effects Study. Natural Resource Report NPS/NRSS/ARD/NRR—2015/996. National Park Service, Fort Collins, CO.

McDonnell, T.C. and T.J. Sullivan. 2014. Comparison of Regional Stream ANC Predictions for the George Washington National Forest Using Spatial and Non-Spatial Regression Modeling. Final Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

McDonnell, T.C. and T. J. Sullivan. 2014. Total Atmospheric Nitrogen and Sulfur Deposition in Forest Service Wildernesses and National Forests Throughout the Conterminous United States. Final Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, **T.C. McDonnell**, A.T. Herlihy, and D.A. Burns. 2014. Critical Loads of Sulfur and Nitrogen for Protection of Acid Sensitive Aquatic and Terrestrial Resources in the Adirondack Mountains. Final Report. Report No. 14-10. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, **T.C. McDonnell**, A.T. Herlihy, and D.A. Burns. 2014. Critical Loads of Sulfur and Nitrogen for Protection of Acid Sensitive Aquatic and Terrestrial Resources in the Adirondack Mountains. Summary Report. Report No. 14-11. New York State Energy Research and Development Authority (NYSERDA), Albany, NY.

Sullivan, T.J. and **T.C. McDonnell**. 2013. Mapping of Nutrient-Nitrogen Critical Loads for Selected National Parks in the Intermountain West and Great Lakes Regions. Report

prepared for the National Park Service, Air Resources Division. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., G.B. Lawrence, S.W. Bailey, **T.C. McDonnell**, and G.T. McPherson. 2013. Effects of Acidic Deposition and Soil Acidification on Sugar Maple Trees in the Adirondack Mountains, New York. NYSERDA Report No. 13-04. New York State Energy Research and Development Authority, Albany, NY.

Sullivan, T.J. and **T.C. McDonnell**. 2012. Application of Critical Loads and Ecosystem Services Principles to Assessment of the Effects of Atmospheric Sulfur and Nitrogen Deposition on Acid-Sensitive Aquatic and Terrestrial Resources. Report prepared for the U.S. Environmental Protection Agency in association with Systems Research and Applications, Corp. E&S Environmental Chemistry, Inc., Corvallis, OR.

Lawrence, G.B., T.J. Sullivan, K.C. Weathers, B.J. Cosby, and **T.C. McDonnell**. 2011. Comparison of Methods for Estimating Critical loads of Acidic Deposition in the Western Adirondack Region of New York. Final Report 11-13. Prepared for the New York State Energy Research and Development Authority. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T. J., G. T. McPherson, **T. C. McDonnell**, S. D. Mackey, and D. Moore. 2011. Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Acidification Effects from Atmospheric Sulfur and Nitrogen Deposition. Natural Resource Reports NPS/NRPC/ARD/NRR—2011/349-382. National Park Service, Denver, Colorado.

Sullivan, T.J., **T. C. McDonnell**, G. T. McPherson, S. D. Mackey, and D. Moore. 2011. Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition. Natural Resource Reports NPS/NRPC/ARD/NRR—2011/302 to 2011/334. National Park Service, Denver, Colorado.

Sullivan, T.J., B.J. Cosby, and **T.C. McDonnell**. 2010. Aquatic Critical Loads and Exceedances in Acid-Sensitive Portions of Virginia and West Virginia. Results of Southeastern Multiagency Critical Loads Research Project. Report prepared for National Park Service, U.S. Environmental Protection Agency, USDA Forest Service, and U.S. Geological Survey. E&S Environmental Chemistry, Inc., Corvallis, OR.

E&S Environmental Chemistry, Inc. (including **T.C. McDonnell**). 2009. Alpine Vegetation Workshop: Response of Alpine and Subalpine Plant Species to Changes in Atmospheric N Deposition. Final Report. Held November 6-7, 2008 in Lakewood, CO. Sponsored by National Park Service and U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (**T.C. McDonnell**, contributor). 2008. Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur Ecological Criteria (Final Report). Report No. EPA/600/R-08/082F. U.S. Environmental Protection Agency, Washington, DC.

Sullivan, T.J., C.T. Driscoll, B.J. Cosby, I.J. Fernandez, A.T. Herlihy, J. Zhai, R. Stemberger, K.U. Snyder, J.W. Sutherland, S.A. Nierzwicki-Bauer, C.W. Boylen, **T.C. McDonnell**, and N.A. Nowicki. 2006. Assessment of the Extent to Which Intensively-Studied Lakes are Representative of the Adirondack Mountain Region. Final Report 06-17. New York State Energy Research and Development Authority, Albany, NY.

Presentations

McDonnell, T.C., M.D. Bell, E. Felker-Quinn, A. Witt. Exceedance of Critical Loads of Nitrogen and Sulfur Deposition across National Parks: Interactive Web Mapping. Presentation for National Atmospheric Deposition Program (NADP) Critical Loads of Atmospheric Deposition (CLAD) Spring 2023 Meeting, May 1, 2024.

McDonnell, T., M. Bell, E. Felker-Quinn. Climate change and air pollution effects on vegetation response in U.S. National Parks. Presentation for National Atmospheric Deposition Program (NADP) Fall 2023 Meeting, October 25, 2023.

McDonnell, T.C., P. Gruendike, M. Deas, D. Ebert. Effects of J.C. Boyle Dam Removal on Thermal Refugia and Implications for Habitat Restoration Priorities. Presentation for Riverine Symposium, March 22, 2023.

McDonnell, T., M. Bell, C. Clark, J. Cosby, C. Driscoll, T. Greaver, B. Knees, J. Phelan, G.J. Reinds, T. Sullivan, A. Talhelm. Climate change and air pollution effects on soil and vegetation of the United States. Presentation for National Atmospheric Deposition Program (NADP) Fall 2022 Meeting, November 17, 2022.

McDonnell, T., D. Ebert. Thermal Infrared Data Collection on the Klamath River – J.C. Boyle Dam to Copco Reservoir. Presentation for Klamath Basin Monitoring Program Meeting June 16, 2022.

McDonnell, T., M. Diabat. Thermal Infrared Imagery Assessment of the Klamath River between J.C. Boyle and Copco Reservoirs. Presentation for Klamath Hydroelectric Project Interim Measure Implementation Committee (IMIC) Meeting Oct. 21, 2021.

Clark, C., J. Phelan, M. Bell, R. Sabo, K. Austin, G. Martin, J. Herrick, K. Novak, J. T. Smith, T. Greaver, R. Dalton, J. Miller, **T. McDonnell**, L. Pardo, N. Pavlovic, C. Driscoll. Recent advances in critical loads research from the US-EPA'S Office of Research and Development. Presentation for National Atmospheric Deposition Program (NADP) Fall 2021 Meeting Oct. 25-29, 2021.

Clark, C., K. Horn, **T. McDonnell**, S. Simkin, C. Driscoll, N. Pavlovic, L. Pardo, K. Wilkins, J. Aherne, M. Bell. Recent advances in Critical Loads research from the US-EPA's Office of Research and Development. International Cooperative Programme on Modelling and Mapping of Critical Levels & Loads and Air Pollution Effects, Risks and Trends (ICP M&M) 36th Task Force Meeting, April 20, 2021. Online meeting.

McDonnell, T., C. Clark, G.J. Reinds, T. Sullivan, and B. Knees. 2021. Regional Critical Loads of Atmospheric Nitrogen Deposition for Terrestrial Vegetation: Case Study and Comparison. Presentation for National Atmospheric Deposition Program (NADP) Critical Loads of Atmospheric Deposition (CLAD) Virtual Seminar Series – Critical loads of N and S for herbaceous species and herbaceous richness. April 28, 2021.

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, T. Sullivan, and C. Clark. 2020. Vegetation Response Models and Regional Critical Loads of Atmospheric Nitrogen Deposition. National Atmospheric Deposition Program Fall Meeting and Scientific Symposium. October 29, 2020. Online meeting (originally scheduled for Knoxville, TN).

McDonnell, T.C., T.J. Sullivan, B. Knees, M. Bell, and E. Felker-Quinn. 2020. Intermodel Comparison of Atmospheric Nitrogen Deposition Estimates for the Conterminous United States and Critical Load Exceedance for Selected National Parks. National Atmospheric Deposition Program Total Deposition Science Committee (TDep), Spring 2020 Meeting. May 12, 2020. Online meeting (originally scheduled for Madison, WI).

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, T. Sullivan, and C. Clark. 2020. Biodiversity Modeling and Critical Loads Assessment in the USA. International Cooperative Programme on Modelling and Mapping of Critical Levels & Loads and Air Pollution Effects, Risks and Trends (ICP M&M) 36th Task Force Meeting, April 22, 2020. Online meeting (originally scheduled for Stockholm, Sweden).

McDonnell, T.C., G.J. Reinds, W. Wamelink, P. Goedhart, M. Posch, M. Doviak, T.J. Sullivan, and C. Clark. 2020. Modeling habitat suitability for temperate forest understory vegetation. Presented at Adirondack Research Forum, Old Forge, NY, February 25, 2020.

Zarfos, M.R., M. Dovciak, G. Lawrence, **T. McDonnell**, and T. Sullivan. 2020. Understanding a 5-year shift in the composition of Adirondack hardwood seedling communities: the role of soil nutrients and climate. Presented at Adirondack Research Forum, Old Forge, NY, February 25, 2020.

McDonnell, T.C. and J. Phelan. 2019. Biodiversity Modeling and Critical Loads Efforts in the USA. 19th Meeting of the UNECE Working Group on Effects: Joint Expert Group on Dynamic Modelling. Sitges, Spain, October 30, 2019.

McDonnell, T.C., T.J. Sullivan, C.T. Driscoll, B.J. Cosby, W.A. Jackson, G.B. Lawrence, D.A. Burns, C.A. Dolloff, C.M. Beier, P.F. Hessburg, N.A. Povak, and K.M. Reynolds. 2019. Regional Stream Acidification and Critical Loads in the Adirondack and Southern Appalachian Mountains Including Interactions with Climate Change. Presented at Society for Freshwater Science Annual Meeting, Salt Lake City, Utah, May 22, 2019.

McDonnell, T.C. 2019. Atmospheric Deposition Effects Modeling for Resource Management on Southern Appalachian National Forests. USFS Deposition Focused Air Resource Management (FARM) Team Meeting, February 13, 2019.

Driscoll, C.T., S. Shao, T.J. Sullivan, **T.C. McDonnell**, B.P. Baldigo, D.A. Burns, and G.B. Lawrence. 2018. Responses of Streams in the Adirondack Mountains to Changes in Atmospheric Deposition of Sulfur and Nitrogen: Past and Future Acidification and Target Loads of Deposition to Promote Resource Recovery. Presented at the Adirondack Acid Rain Conference in Saratoga Springs, NY. November 29, 2018.

McDonnell, T., C. Clark, M. Bell, and T. Sullivan. 2018. Habitat Suitability for Understory Vegetation – Critical Loads Development and Assessment. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Albany, NY, November 6, 2018.

McDonnell, T. 2017. Modeling Effects of Climate Change and Atmospheric N and S Deposition on Terrestrial Biodiversity in the United States. 17th Meeting of the UNECE Working Group on Effects. Joint Expert Group on Dynamic Modelling. Sitges, Spain, October 25-27, 2017.

McDonnell, T. 2017. Modeling Habitat Suitability for Aquatic Biota in the Southeastern United States. 17th Meeting of the UNECE Working Group on Effects. Joint Expert Group on Dynamic Modelling. Sitges, Spain, October 25-27, 2017.

Burns, D., G. Lawrence., T. Sullivan, C. Driscoll, S. Shao and **T. McDonnell**. 2017. Episodic Acidification in the Adirondack Region of New York: Spatial Patterns and Evidence of Recovery. NADP Fall Meeting, San Diego, CA, October 30-November 3, 2017.

Zarfos, M.R., M. Dovciak, G.B. Lawrence, **T.C. McDonnell**, and T.J. Sullivan. 2017. Effects of Acidic Deposition and a Soil Acidification Gradient on Forest Understory Plant Richness And Composition in the Adirondack Mountains, New York. Ecological Society of American Annual Meeting, Portland, OR, August 6-11, 2017.

McDonnell, T. 2016. Dynamic Vegetation Modeling in the Eastern US. 16th Meeting of the UNECE Working Group on Effects. Joint Expert Group on Dynamic Modelling. Sitges, Spain, October 26-28, 2016.

Lapenis, A., A. Buyantuev, S. Jiang, G. Lawrence, T. Sullivan, **T. McDonnell**, and S. Bailey. 2016. Spring Phenology – A Newly Identified Ecophysiological Role of the Deciduous Forest Floor. American Geophysical Union Fall Meeting, San Francisco, CA, December 12-16, 2016.

Lawrence, G.B., T.J. Sullivan, **T.C. McDonnell**, S.W. Bailey, M. Dovciak and M.R. Antidormi. 2016. Influence of Soil-Base Availability on Composition and Structure of Adirondack, NY, Sugar Maple-Beech Forests. Soil Science Society of America Annual Meeting, Phoenix, AZ, November 6-9, 2016.

Sullivan, T., **McDonnell, T**., Beier, C, Belyazid, S., Burns, D., Clark, C. , Cosby, B., Dovciak, M., Driscoll, C., Jackson, W., Lawrence, G., Reinds, G., Sams, C., Shao, S., and Whalen, M. 2016. Ecosystem Recovery from S and N Deposition and Associated Critical Loads in Context of Changing Climate. NADP Fall Meeting, Santa Fe, NM, November, 2016.

Barna, M., T. Moore, T. Sullivan, **T. McDonnell**, and T. Thompson. 2016. Simulating the Contribution of Emissions from Oil and Gas Development to Regional Nitrogen Deposition at National Parks in the Intermountain West. International Global Atmospheric Chemistry, Breckenridge, CO, September 26-30, 2016.

McDonnell, T., S. Belyazid, L. Bonten, C. Clark, G.J. Reinds, and T. Sullivan. 2016. Exploring Coupled Dynamic Biogeochemical and Vegetation Models in Temperate Forest Ecosystems of the Eastern United States. 26th CCE Workshop and 32nd ICP M&M Task Force Meeting, Dessau, Germany, April 19-22, 2016.

Lawrence, G.B., D.S. Ross, T.J. Sullivan, **T.C. McDonnell**, S.W. Bailey, and J.E. Dukett. 2015. Combining Long-Term Watershed Monitoring at Buck Creek with Spatially Extensive Ecosystem Data to Understand the Processes of Acid Rain Effects and Recovery. American Geophysical Union Fall meeting. San Francisco, CA, December 14-18, 2015.

McDonnell, T.C. and Sullivan, T.J. 2014. Evaluating Effects of Atmospheric N and S Deposition and Climate on Forest Ecosystem Services Based on the Critical Loads Paradigm. International Union of Forest Research Organizations. XXIV World Congress, Salt Lake City, UT, October 5-11, 2014.

Sullivan, T.J., **T.C. McDonnell**, K. Reynolds, P. Hessburg, N. Povak, and B. Salter. 2013. Ecosystem Management Decision Support (EMDS). Surface Water Acidification in the Southern Appalachian Mountains. ESE/EMDS Workshop. U.S. Forest Service Region 8 Air Resource Management, Asheville, NC, April 9th, 2013.

Sullivan, T.J. and **T.C. McDonnell**. 2012. Critical Loads Approach to Ecosystem Services. Presented at 2012 NADP Annual Meeting and Scientific Symposium: The NADP Cooperative: State, Local and Tribal Perspectives, Portland, ME, October 2-5, 2012.

Sullivan, T., **T.C. McDonnell**, B. Cosby, C. Driscoll, G. Lawrence, S. Bailey, H. Sverdrup, S. Belyazid, P. Hessburg, N. Povak, and K. Reynolds. 2012. Modeling Critical Loads Using Process Models: Recent Efforts. Presented at NADP Conference, Portland, OR, April 2012.

Reynolds, K., P. Hessburg, T. Sullivan, N. Povak, **T.C. McDonnell**, B. Cosby, and W. Jackson. 2012. Spatial Decision Support for Assessing Impacts of Atmospheric Sulfur Deposition on Aquatic Ecosystems in the Southern Appalachian Region. Proceedings of the 45th Hawaiian International Conference on System Sciences. 4-7 January 2012, Maui, Hawaii. 10 pp.

McDonnell, T.C., T.J. Sullivan, K. Reynolds, P. Hessburg, N. Povak, and B. Salter. 2011. Biological Response & Sulfur Critical Loads. Presented at EMDS Workshop at NADP Meeting, Pensacola, FL, May 5, 2011.

Sullivan, T.J., **T. C. McDonnell**, G. T. McPherson, E. Porter, S. D. Mackey, and D. Moore. 2011. Use of GIS to Evaluate Sensitivity of I&M Parks to Effects from Atmospheric Nitrogen Deposition. Presented at The George Wright Society Conference on Parks, Protected Areas, & Cultural Sites, New Orleans, LA, March 14-18, 2011.

Sullivan, T.J., Cosby, B.J., **McDonnell, T.C.**, and Driscoll, C.T. 2011. Modeling Critical Loads, New York and Beyond. Presented at New York State Research and Development Authority (NYSERDA) Conference, Environmental Monitoring, Evaluation, and Protection in New York: Linking Science and Policy. Albany, NY, November 15-16, 2011.

Sullivan, T.J., B.J. Cosby, and **T.C. McDonnell**. 2010. Steady State Aquatic Critical Loads for Acid Sensitive Portions of Virginia and West Virginia. Final Results of SE Multiagency Critical Load Project. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Memphis, TN, April 20-21, 2010.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, **T.C. McDonnel**l, Q. Zhou, and D. Burns. 2010. Development of Critical Loads for the Protection of Acid-Sensitive Resources in the Adirondack Mountains, New York. Presented at Critical Loads Ad Hoc (CLAD) Committee, NADP Meeting, Memphis, TN, April 20-21, 2010.

Sullivan, T.J., B.J. Cosby, **T.C. McDonnell**, C.T. Driscoll, A.T. Herlihy, and D.A. Burns. 2010. MAGIC Model Estimates of Critical Load of Sulfur Deposition to Protect Acid-Sensitive Resources in the Adirondack Mountains, New York. Presented at 2010 National Atmospheric Deposition Program Annual Meeting & Scientific Symposium, Networking the Networks, Lake Tahoe, CA, October 19-21, 2010.

Hessburg, P., K. Reynolds, T. Sullivan, B. Jackson, M. Povak, B. Salter, and **T. McDonnell**. 2010. Progress on Implementation of a Decision-Support System to Assess Critical Loads of Atmospheric S Deposition in the Southeastern US. Presented at 2010 National Atmospheric Deposition Program Annual Meeting & Scientific Symposium, Networking the Networks, Lake Tahoe, CA, October 19-21, 2010.

Sverdrup, H., T. Sullivan, B. Nihlgård, S. Belyazid, **T. McDonnell**, and B. Rihm. 2010. Testing the Feasibility of Using ForSAFE---VEG for Mapping Critical Loads for Nitrogen Based on Biodiversity in the Rocky Mountains Region. Presented at Critical Loads Ad Hoc (CLAD) Committee Meeting, Lake Tahoe, CA, October 19-21, 2010.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, **T.C. McDonnell**, Q. Zhou, and D.A. Burns. 2009. Use of Critical Deposition Loads to Inform Environmental Protection Strategies. Presented at NYSERDA Conference. Environmental Monitoring, Evaluation, and Protection: Linking Science and Policy, Albany, NY, October 14-15, 2009.

Sullivan, T.J., B.J. Cosby, and **T.C. McDonnell**. 2009. Critical Loads for Protection of Aquatic Resources in the Blue Ridge, Ridge and Valley, and Appalachian Plateau Ecoregions of Virginia and West Virginia. Presented at 2009 Annual Meeting and Scientific Symposium. National Atmospheric Deposition Program, Saratoga Springs, NY, October 6-9, 2009.

Sullivan, T., B. Cosby, and **T.C. McDonnell**. 2009. Aquatic Critical Loads in Virginia and West Virginia. Research Results. Presented at Critical Loads Ad Hoc (CLAD) Meeting, Pensacola, FL, April 2009.

Sullivan, T., C. Driscoll, B. Cosby, D. Burns, A. Herlihy, and **T.C. McDonnell**. 2009. Critical Loads to Adirondack Lake Watersheds. Progress Report. Presented at Critical Loads Ad Hoc (CLAD) Meeting, Pensacola, FL, April 2009.

Sullivan, T., C. Driscoll, B. Cosby, D. Burns, A. Herlihy, and **T. McDonnell**. 2009. Critical Loads to Adirondack Lake Watersheds. Progress Report. CLAD Meeting, Pensacola, FL, April 2009.

Sullivan, T., **T. McDonnell**, and B. Cosby. 2008. Progress on the Multi-Agency Critical Loads Project. NADP Meeting, Madison WI. October, 2008.

Mankiewicz, P.S. and **T.C. McDonnell.** Sustainable Green Roof Design: Optimizing Water Budgets Through Wastes-into-Resources Technologies in the Bronx. Fourth Annual International Greening Rooftops for Sustainable Communities, Conference, Awards & Trade Show: Boston, MA. May 2006.

McDonnell, T.C. Bioengineering for Contaminated Soil and Water in the Harlem River Valley. Bronx Council for Environmental Quality Water Resources Conference: Manhattan College, New York, NY. March 2005.

McDonnell, T.C. Estimating Pollutant Loading to the Bronx River. Westchester County Parks Department: White Plains, NY. October 2004.

McDonnell, T.C. Groundwater Dynamics at Sleepers River, VT: A MODLFOW Simulation. American Water Resources Association- Salt City Chapter Symposium: SUNY College of Environmental Science and Forestry, Syracuse, NY. April 2004.

McDonnell, T.C. Lake Sensitivity to Acidic Deposition in the Adirondack Mountains, NY. Biogeochemistry Symposium: SUNY College of Environmental Science and Forestry, Syracuse, NY. December 2003.

Sullivan, T.J., C. Boylen, B. Cosby, C. Driscoll, I. Fernandez, A. Herlihy, **T. McDonnell**, E. Miller, D. Moore, S. Nierzwicki-Bauer, N. Nowicki, K. Snyder, R. Stemberger, and J. Sutherland. Assessment of Extent to Which Intensively-Studied Lakes are Representative of the Adirondack Mountain Region, NY. American Geophysical Union Conference. Poster. San Francisco, CA. December 2003.

McDonnell, T.C. and T. Endreny. Dynamic Simulation of Storm Induced Geomorphic Adjustments in Onondaga Creek, NY Using CONCEPTS: a channel evolution/sediment transport model. Spotlight on Student Research and Outreach. Poster. SUNY College of Environmental Science and Forestry, Syracuse, NY. April 2003.

McDonnell, T.C., J. Padilla, S. Harris, and D. Fallon. Water Quality Analysis of Magdalena Bay, Mexico: Determining Sources of Anthropogenic Eutrophication. The School for Field Studies, Center for Coastal Systems Research: Puerto San Carlos, Baja California Sur, Mexico. May 2001.